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Management of Hospitals Wastewater

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DEDICATION

To my husband

ACKNOWLEDGMENT

I would like to express my thanks to ***Dr. Bashir M. El Hassan*** for his relative guidance and encouragement. My thanks also to the staff in the studied hospitals, Federal and State Ministries of health for their contribution and assistance in achieving this study.

Special thanks to my family, those who were supporting me all the time.

ABSTRACT

Hospital wastewater management is an integral part of human welfare .The improper wastewater management reduces the over all benefits of health care, increase the environmental risks, and decrease the productivity.

Wastewater from hospitals and laboratories is of a similar quality to urban wastewater, but it may contain various potentially hazardous components. The most recognized metalic pollutants of concern are nickel, copper, zinc, silver and mercury. On the other hand, non-metallic pollutants of concern include cyanide, phenolic compounds such as picric acid, formaldehyde and other solvents.

There are 93 hospitals in Khartoum State with 6801 beds. Every day nearly 2585 cubic meters of wastewater is discharged from these hospitals to the subsurface water, Nile River, and the municipal net without pretreatment or awareness regard the hazardous characteristics of this waste. Annually more than 68 kg of pure silver is discharged from x-ray units to the hospitals sewers without recovering.

As a result of these practices water sources and soil may be polluted and thus, community is exposed to infectious and toxic effects.

In this study laboratory tests were performed to estimate the characteristics of hospital waste streams and to specify the most occurring hazardous elements. This study made an approach to perform a Hospital Pollution Prevention Checklist and developed a designing program for septic tank units.

الخلاصـــــــــة

إن إدارة المخلفات السائلة للمستشفيات جزء مكمل لصحة و رفاهية الإنسان، و الإدارة الغير سليمة لهذه المخلفات السائلة تخلق العديد من المخاطر البيئية و تقلل من فوائد الرعاية الصحية و تؤثر سلبا على معدل الإنتاج.

المخلفات السائلة من المستشفيات و المعامل تتشابه في الخصائص مع مخلفات الصرف الصحي في المدن، إلا أنها قد تحتوى علي العديد من المواد الخطرة. من بين العناصر الخطرة المعدنية: النيكل، النحاس، الزنك، الفضة، و الزئبق. أما المواد غير المعدنية فهي السيانايد، و مركبات الفينول مثل حمض البكريك و الفورمالدهايد و غيره من المذيبات.

توجد 93 مستشفى في ولاية الخرطوم بعدد أسرة يبلغ 6801 سرير. و يقدر إنتاجها بحوالي 2585 متر مكعب في اليوم من المخلفات السائلة ، هذه المياه يتم تصريفها إلى المياه الجوفية، نهر النيل، و شبكة الصرف الصحي من دون معالجة مبدئية أو وعي لمخاطر هذه المخلفات. هنالك اكثر من 68 كجم من الفضة النقية يتم دفقها سنويا من وحدات الأشعة إلى المجاري من دون استرجاع.

نتيجة لهذه الممارسات يزداد احتمال تلوث التربة و مصادر المياه العذبة بمياه الصرف الصحي مما يعرض المجتمع بذلك للعدوي والسموم .

في هذه الدراسة تم أخذ عينات من خمس مستشفيات و تم إجراء التجارب المعملية لمعرفة خصائصها و تحديد العناصر الأكثر تلويثا للبيئة.

كان نتاج هذه الدراسة تقديم قائمة للوقاية و التقليل من التلوث في المستشفيات و عمل برنامج لتصميم أحواض التخمير بواسطة الحاسوب.

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CHAPTER ONE

INTRODUCTION

In modern societies proper management of wastewater is a necessity not an option. However the collection and safe disposal of human wastes are among the most important problems of environmental health. All water-related diseases such as cholera and typhoid fever are transmitted through similar fashion through the ***"long cycle"***: ***an infected individual*** spreads the disease via ***sewage***, which, if untreated and disposed inadequately, results in ***water pollution***. Farmers often use polluted waters to irrigate food crops; the long transmission loop is closed when individuals eat ***food*** that has been contaminated with polluted irrigation water or drink ***water*** that has been contaminated by sewage. More individuals fall sick, and the cycle is repeated.

The construction of sewerage systems alone cannot break this long cycle. Collecting the sewage of city is of major benefit because it removes a potential health hazard from polluted areas where the risk to public health is the greatest. But the threat to the population remains as long as the untreated wastewater is disposed into water recipients and then used to supply potable water to irrigate food crops that are eaten raw.

Alternative on-site disposal systems such as pit latrines, aqua privies or infiltration wells used in conjunction with septic tanks do not remove the danger to public health either. Sewage from these units may infiltrate to the shallow groundwater from which potable water is extracted, resulting in ground water pollution [(1)]. The end result of operating under the assumption that ***"solution to pollution is dilution"*** [(2)] is the deterioration of natural water resources, whose natural self-purification capacity is exceeded.

The wastewater management hierarchy in its most general form is:

1. Reduce wastewater production.
2. Reduce toxicity of wastewater.
3. Treat wastewater before disposal.
4. Reuse wastewater after further treatment.
5. Dispose in an environmentally sound manner [(3)].

We cannot prevent the production of the human excreta, but we can use less water to achieve the same purpose (e.g. flushing toilet) and hence produce less wastewater. We can avoid toxicity of wastewater by preventing toxic waste to be disposed with biodegradable organics [(3)].

Wastewater from hospitals and laboratories are of a similar quality to urban wastewater, but may also contain various potentially hazardous components [(4)]. However, because of large flows from such facilities the mass contribution for some pollutants can be significant [(5)]. Among the metal pollutants of most concern are nickel, copper, zinc, silver and mercury. Other non-metallic pollutants of concern include cyanide, phenolic compounds such as picric acid, formaldehyde and other solvents [(6)], (see annex (1)).

Literature describing hospitals and laboratories wastes is not readily available .It is to be expected that the treatment problems posed by these wastes will be unique to the institution involved; therefore a variety of treatment methods may be needed. Often where chemicals are used in conjunction with biological contaminants, the chemical alone may be sufficient to inactive the biological component [(7)].

Although hospital wastewater is often regarded, as an important source of pathogenic microorganisms, there is no evidence that hospital wastewater carries higher load of pathogenic microorganisms than city sewage and due to the dilution factor introduced, hospital effluents are more likely to improve the quality of city sewage than to "over load" it with pathogens, because the great majority of clinically healthy carriers of infectious disease are not hospitalized and receive no treatment [8].

It is to be said that photographic industry as a whole uses about one quarter to one third of all the silver put to industrial use and about two third of this quantity is potentially to be recovered from the x-ray departments: from the exhausted processing solutions, discarded film materials and photographic papers [9].

Wastewater is ***hazardous*** if it displays any of the four hazardous characteristics: ignitability, corrosivity, reactivity, or toxicity (containing heavy metal or organics) [10]

- Ignitability:
    1. A liquid waste with flash pointless than 140F^{o};
    2. Any waste that is an ignitable compressed gases;
    3. Any waste material that can cause fire through friction, absorption of moisture or spontaneous chemical change such as picric acid [11].
- Corrosivity:
    1. An aqueous with a pH less than or equal to 2.0;
    2. An aqueous with a pH greater than or equal to 12.5;
    3. A liquid waste that corrodes plain carbon steel at a rate greater than 0.25 inch per year (6.35 mm/year) [11].
- Reactivity:

  A waste that:
    1. Is normally unstable and readily undergoes violent changes without detonating;
    2. Reacts violently with water;
    3. Forms potentially explosive mixtures with water;

4. Generates toxic gases or fumes when mixed with water;
5. Is a cyanide or sulfide that can generate toxic gases, vapour or fumes such as sodium cyanide;
6. It is a capable of detonation or explosive reactions under certain condition [11].

- Toxicity:

This characteristic is based on the amount of certain heavy metals, pesticides, semi-volatile and volatile organic compounds [11]. In hospitals only heavy metals and volatiles are included, (see annex (1)).

1.1 Thesis rationale:

This thesis focuses on improving management of hospitals wastewaters in Khartoum state, where municipal sewerage services only 5-7 %[12] of the total population and water table is high. These facts raise the following issues: ***How can wastewaters from hospitals be properly and safely treated and disposed of in Khartoum state, particularly those hospitals with on-site treatment systems? What are the types of on-site treatment systems used there? Which types of pollutants are discharged in hospitals? And among these types of pollutants, which one can easy be reduced? And which is the simple practice can be used to achieve this?***

1.2 Hypothesis:

This study attempts to vertify the following hypothesis:

1. The quantities of wastewater produced from hospitals in Sudan and standard used are unknown;
2. The design capacity of the majority of the on-site treatment systems used in hospitals is less than the capacity needed;

3. Large amounts of chemicals from laboratories, cleaning and disinfection processes including heavy metals and phenolic compounds are discharged regularly into hospitals sewers;
4. The radioactive wastewaters are discharged to the sewers without precautions or treatment;
5. The large amounts of silver-recovable from fixer solution in x-ray units are discharged without recovering into hospitals sewer.

1.3 Scope:

The scope of this study is to introduce safe management of hospitals wastewaters viz.:

- Safe collection;
- Safe treatment (wastewater and sludge);
- Safe disposal and / or reuse.

1.4 Objectives of the study :

This study is carried out to achieve the following objectives:

1. To estimate quantities of wastewater produced by the main hospitals in Khartoum state;
2. To identify waste streams from hospitals;
3. To determine the characteristics of wastewater including of its properties (COD, BOD, pH, S.S);
4. To assess the collection, treatment, disposal and reuse systems if any of hospitals wastewater in Khartoum state;
5. To estimate amounts of silver that can be recovered from the fixer solutions in x-ray units;
6. To produce appropriate proposal for acceptable treatment, disposal and/or reuse system wastewater with design out lines.

1.5 Research methodology:

The methodology used for this research includes the literature review and field survey as a primary resource of data. The various tasks involved in this research including the following:

Task1: Literature review of characteristics and identification of hospital waste streams to determine the types of pollutants discharged from hospitals into sewers;

Task2: Preparation of the questionnaire for field survey;

Task3: Field survey in the studied hospitals in Khartoum state as a source of a primary data with photo-documentation. The detailed methodology for this task is discussed in chapter three;

Task4: Collection wastewater samples from various sources in the biggest studied hospitals;

Task5: Laboratory analysis for the colleted samples including COD, BOD, pH and S.S. tests to characterize the hospital waste streams;

Task6: Analysis of the collected data from the field survey and laboratory experiments.

CHAPTER TWO
LITERATURE REVIEW

The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with economic, social, and political concerns [13]. The major elements of wastewater management systems and associated engineering tasks are identified in table (2.1).

Table (2.1) Major elements of wastewater management systems and associated engineering tasks[13]

Element	Engineering Tasks
Source of generation	Estimation of quantities of wastewater, and determination of wastewater characteristics.
Source control	Design of onsite systems to provide partial treatment of the wastewater before it is discharged to collection systems *.
Collection	Design of sewers used to remove wastewater from the various source of generation.
Transmission and pumping	Design of large sewers used to transport wastewater to treatment facilities or to other locations for processing*.
Treatment (wastewater and sludge)	Selection, analysis, and design of treatment operations and processes to meet specified treatment objectives related to the removal of wastewater contaminants of concern.
Disposal and reuse	Design of facilities used for the disposal and reuse of treated effluent in the aquatic and land environment, and the disposal and reuse of sludge on land.

* Not covered in this study

2.1 Source of generation:

2.1.1 Estimation of wastewater quantities:

Hospitals wastewaters include all wastewaters collected from heath-care establishments, research facilities and laboratories [4], rates of water used and average flows of wastewater are listed in table (2.2) according to English, American and French standards.

Table (2.2) Average of water and wastewater flow to and from hospitals according to English, American and French standards

Type of Standard	Type of Hospital	Unit	Water Flow l/day	Wastewater flow L/unit. day Range	Wastewater flow L/unit. day Typical
American[13]	Medical	Bed Employee	700-1200	500-950 20-60	650 40
	Mental	Bed Employee	400-600	300-550 20-60	400 40
English[14]	Medical	Bed	950-1890	570-950	-
French[15]	Medical	Bed	300	-	-

2.1.2 Characteristics and identification of hospital waste streams:

There are numerous chemicals used in various areas throughout hospitals. For many chemicals the only option may be collection for disposal as a hazardous wastewater [6]. The following information concerns the identification of several waste streams that should be collected and disposed of as a hazardous waste.

The main areas discussed include:

- Laboratories;
- Dialysis;

- Gross Pathology and Necropsy;
- Central sterilization and infectious waste;
- Patient care areas;
- Pharmacy;
- X-ray unit;
- Radioactive therapy;
- Radioactive diagnostic;
- Facilities.

2.1.2.1 Laboratories:

Hospitals and medical facilities have numerous associated laboratory operations. The in-house labs and similar contract labs perform a variety of functions that commonly include but are not limited to *research, chemical pathology, hematology, histology, pathology* (*histopathology*), *microbiology*, and *immunoldiagnostics* [(6)]. These varied laboratories pose one of the largest potentials for pollutants discharge to sanitary sewer at hospital; table (2.3) summarizes pollutants produced in each laboratory.

Table (2.3) Types of pollutants produced in each laboratory

Type of laboratory	Type of pollutants produced
Chemical pathology & Haematology	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc and picric acid.
Histopathology	Mercury, chromium, glutaraldehyde, formaldehyde, alcohols, xylene and other solvents
Microbiology	Mercury
Immunodiagnosis	Mercury, copper and sulphate

There are typically a wide variety of processes and testing conducted in a number of different laboratories locations. Many of the activities produce hazardous waste; examples from some of the more common activities are described below.

2.1.2.1.1 Chemical pathology lab:

The lab. work conducted can include common blood and other body fluid parameters. Common analytics include such things as glucose, albumin, calcium and chloride. The majority of lab analysis is now run on automated systems or other instruments that use very small volumes of sample and reagents [(6)].

2.1.2.1.2 Hematology lab:

Cell sorting and counting instruments use a cyanide-containing cell lysing solution. A small quantity of the solution is used for each sample, which is then diluted with a saline solution during analysis. The cyanide concentration in the final waste solution is usually below the hospital's discharge limit [(6)]. There are several other waste streams in haeomatology and chemical pathology labs; some of them are listed below[(6)]:

- Chromic acid solutions, which is used for cleaning glassware;

- Bouin's solution contains formaldehyde, and is used for washing bone marrow cell and a preservative;
- Chloroform and methylen chloride, which are used to extract blood and urine samples for analysis by gas chromatography (GC);
- Atomic absorption (AA), which is used to determine copper and other trace metals in blood and other samples;
- Xylenes for extraction and slide cleaning.

Other metal-containing reagents that are used in these labs include the following:

- An albumin method uses a reagent with 80g $CrK(SO_4)_2$ per liter;
- A total protein method uses reagent with 1.5g of $CuSO_4.5H_2O$ per liter;
- A preservative for stool samples contains a concentrated copper solution;
- A glucose test kit uses zinc.

Generally, the pollutants of greatest concern are cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, picric acid and zinc [(6).]

2.1.2.1.3 Histopathology lab.:

The most common hazardous materials used as a preservative and fixatives are used to prepare specimens such as glutaraldehyde, formaldehyde, alcohols, xylene and other solvents. It should be noted that all the above solvents may consider to be non-hazardous waste, if they are stored for 14 to 21 days before discharging to sewers. The most two hazardous materials used as a tissue fixative are Zankar's solution which contains72g of mercury and 5g of chromium per liter, and B5 which contains 37g of mercury per liter [(6)].

2.1.2.1.4 Microbiology lab.:

Most of the chemicals usage in this lab is for preparation of slides. Many of the stains contain heavy metals or other hazardous ingredients and several stains contain mercury, such as hemotoxyline [(6)].

2.1.2.1.5 Immunodiagnosis lab.:

Several slide preparation solutions used in the immunodiagnosis lab contain heavy metals such as "Thimerosal" which contains mercury, and Copper Sulfate solution which is used for at least one slide preparation method [(6)].

2.1.2.2 Dialysis:

The wastewater from a dialysis center commonly consists of effluent from patient treatment and from cleaning and disinfection of equipment. The dialysate from patient treatment consists of a saline solution and patient waste products.

Domestic supply water is treated before use in dialysis; it is deionized by reverse osmosis (RO) filtration after pretreatment with sand and charcoal filtration and often softened to remove calcium and magnesium. The RO membrane must be periodically disinfected, usually by bromine or formaldehyde, which is finally discharged to sewer. A solution of peracetic acid, acetic acid and hydrogen peroxide is now available for this function with advantage of lower exposure of both employees and patients to formaldehyde, which is a suspected carcinogen [6]. The dialysis units themselves, the system tubing and pumping equipment are also treated on a regular basis with formaldehyde, which can be changed with peracetic acid [6].

2.1.2.3 Gross pathology and Necropsy:

In gross pathology, the larger tissue and organ specimens are prepared and stored. These procedures often include of alcohols, formaldehyde and some metal- containing fixative as silver stain and Zankar's fixure [6].

2.1.2.4 Central sterilization:

Most hospitals have one or more central supply processing and distribution centers that wash and sterilize the reusable equipment. The most common disinfection procedures used include liquid sterilants, steam, and ethylene oxide. The sterilization method is most often chosen by the properties of the equipment.

Liquid "cold" sterilant such as glutaraldehyde, formaldehyde and Phenols are common in hospitals, they are primarily use on equipment that either can not be subjected to the high temperatures or moisture in autoclaves, can not withstand the oxidative properties ethylene oxide, or must have a fast turn around time [(6)].

Steam sterilization (autoclaving) is used on most equipment that is rugged enough to handle the heat and moisture, and does not absorbent surfaces. This method produces little or no chemical waste [(6)].

Ethylene oxide (EtO) is a gaseous, cold sterilant that is applied to equipment held in sterilizing chamber. Other proposed alternative sterilization methods include electron beam, gas plasma and microwave. None of these appear to pose significant risk to sanitary sewer [(6)].

2.1.2.5 Patient care areas:

Patient care areas include sugary, nursing and hospital room areas the wastewater discharged from this unit is very similar to domestic wastewater from a hotel or residence. The primary contributing flows include showers, rest rooms and cleaning. The potential concerns include disinfection supplies (phenolics), the introduction of medicines and other pharmaceutical products, and spills from mercury-containing equipment such as thermometer and blood pressure cuffs [(6)].

2.1.2.6 Pharmacy:

The primary function of the pharmacies is to dispense medications and prepare IV solutions. The IVs are salt solutions with the additions of medicines or nutrients. The two main sources of selenium and zinc pollutants are selenium shampoos and zinc ointments, which may be the hospital’s biggest contribution of these pollutants. In addition to other heavy metals such as silver, cadmium, chromium, copper, cyanide, lead, mercury and nickel [(6)].

2.1.2.7 X-ray unit:

Photographic fixing and developing solutions are used in x-ray departments. The fixer usually contains 5-10% hydroquine, 1-5% potassium hydroxide, and less than 1% silver. The developer contains sodium thiosulphate and approximately 45% glutaraldehyde. Acetic acid is used in both to stop baths and fixer solutions. X-ray processor systems may be periodically cleaned with a chromic acid solution such as *Kodak's Liquid Developer System Cleaner*, this solution contains a high level of chromium [(6)].

2.1.2.8 Radioactive therapy:

Waste from radioactive therapy unit contains lead, cadmium and other metals and low-level radioactive waste produced from washing, filling and other working of the casts [(6)].

2.1.2.9 Radioactive diagnostic:

Radioactive wastes result from the use of tracer and others radioactive diagnostic and treatment procedures. The main radionuclides used are ^{32}P, ^{125}I, ^{131}I, which are of a much higher level of activity with half-life of 13.6, 60 and 8 days respectively. In addition to low-level liquid waste from patient's excreta and all body fluids, and washing apparatus, utensils, clothes, and cleaning of patient wards [(4)]

2.1.2.10 Facilities:

A hospital's facilities department is responsible for general maintenance and operations of the building and grounds. In most respects, these activities are the same as for any business or industry of a similar size. The more important item for hospitals and medical facilities is laundry. Laundry facilities wash hospital and surgery linens including sheets, pajamas, towels, surgery scrubs and wash cloths [(6)].

2.2 Wastewater collection systems:

Wastewater sewerage systems can be classified into three major types; conventional, simplified, and settled sewers.

2.2.1 Conventional sewerage:

Conventional sewerage is also termed deep sewers. This term is results from the fact that in actual practice the sewerage pipes are laid deep beneath the ground. There are a number of reasons for the relatively great depth of the pipes. A minimum velocity is needed to insure that self-cleansing condition occur at least once daily (usually 0.75 m/s [16]). Combined with a minimum specified diameter (usually 150 mm-internal diameters). Added to this is the specification for a minimum depth of burred pipes to avoid interference with road traffic and other services (minimum 0.9 to 1.2m [16]) (see figure (2.1)). Pumping is generally required at various stages of the sewer pipe network, especially if the landscape is fairly flat. The costs of the pipes, inspection manholes, pumps and pumping stations and their construction/installation are therefore high [17]. The costs of operation and maintenance are correspondingly high [18].

2.2.2 Simplified sewerage:

Simplified sewerage is also known as shallow sewers. A gain the term reflects the nature of the shallower placement of the pipes. The purpose of simplified sewers is to reduce the cost of operation and maintenance. Minimum depth of cover of pipes can as low as 0.2 m when there only light traffic. Manholes can be replaced by inspection cleanouts because of the shallow of pipes [19]. In a variation in the simplified sewers the pipe layout passes through property lots (condominial) rather than on both sides of a street (conventional) (see figure (2.2)). Cost of construction can be 30 to 50% les than conventional sewers depending on local conditions [18].

2.2.3 Settled sewerage (small bore sewerage):

Settled sewerage refers to sewers for conveying wastewater that has been settled, for example in septic tank. The origin of settled sewerage is to convey overflow from septic tanks where the soil cannot cope or absorbed the overflow. This usually occurs when the groundwater table is high, or where the soil permeability is low, or where there are rock outcrops. It can also be used when effluent from septic tanks pollutes groundwater and it is necessary to convey the effluent off-site and treat it. Because there are no solids that can potentially sediment the sewers pipes, there is no requirement for the self-cleansing velocity [20]. Smaller pipes and lower gradients can be used. The cost of settled sewers is between a third and a half of conventional sewers [18]. Where there is no existing septic tank, an interceptor box or tank can be used. It functions like a septic tank and designed in the same way (see figure (2.3)).

2.3 Hospitals wastewater treatment:

The hospitals should ideally be connected to a sewage system, and where there are no sewage systems, technically sound on-site sanitation should be provided either simple techniques, such as pit latrine, ventilated pit latrine, and pour flush latrine, or more advanced, such as septic tank, and aqua privy.

The basic principle underlying effective wastewater treatment is a strict limit on the discharge of hazardous liquids to sewers.

2.3.1 Treatment of hazardous liquid wastes:

Management of all hazardous wastes starts with waste minimization efforts, and waste categorization, according to these, WHO recommended the following treatment methods for the hazardous liquid wastes:

2.3.1.1 Infectious waste:

All the infectious waste, such as excreta from patients with enteric diseases (e.g. cholera) will be collected and treated with chemical disinfectant [4].

2.3.1.2 Pharmaceuticals:

Moderate quantities of relatively mild liquid or semi-liquid pharmaceuticals, such as the solution containing vitamins, cough syrups, intravenous solutions, eye drops, etc. (but not antibiotics or cytotoxic drugs), may diluted in a large flow of water and discharged into municipal sewers. Large amounts of pharmaceuticals should not be diluted and discharged into sewers (except for certain very mild solutions, such as vitamins preparations), and may be return to the supplier [4].

2.3.1.3 Cytotoxic waste:

Cytotoxic waste is highly hazardous and should never be discharged into the sewerage system. The best method to treat the cytotoxic waste is chemical degradation methods, which convert cytotoxic compounds into non-toxic/ non-genotoxic compounds. The methods are appropriate for developing countries. Most of these methods are relatively simple and safe; they include oxidation by potassium permanganate ($KMnO_4$) or sulfuric acid (H_2SO_4), denitrosation by hydrobromic acid (HBr) or reduction by nickel or aluminium [4].

2.3.1.4 Chemical waste:

Non-recyclable, general chemical waste, such as sugars, amino acids, and certain salts may be discharged into sewers, but conditions for discharge may include restrictions on pollutant concentrations, content of suspended solids, temperature, pH, and sometimes rate of discharge[4]. Unauthorized discharge of hazardous chemicals can be dangerous to sewage treatment workers and may adversely affect the functioning of sewage treatment works.

Petroleum spirit, calcium carbide, and halogenated organic solvents should not be discharged into sewers [4]. Other possibilities for disposing of hazardous chemicals include return to the original supplier, who should be equipped to deal with them safely. Use of certain products for non-medical purposes may also be considered; for example, use of out dated disinfectants to clean toilets is often acceptable.

For the big amount of silver that produced in x-ray units from used fixer solutions, there are several methods can be used to recover it, they are enumerated as follows [21]:

1. *Electrolytic methods*, based upon the fact that if two electrodes are put into a fixer solution which carries silver in it and a direct current is passed from one electrodes to the other then nearly pure silver plates on the cathodes;
2. *Metallic replacement*, based upon the fact that when a metal such as copper or iron or zinc is put into a solution which has a silver salt in it an exchange takes place in which the base metal dissolves to replace the silver and the silver is deposited out of solution;
3. *Chemical methods* (called sludging), based upon interactions occurring when certain chemicals are added to a silver – loaded fixer and silver is precipitated in a finely divided state; and
4. *Galvanic methods*, base upon a process which immerses in the fixer solution two dissimilar metals in contacts with each other, with the result that silver from the solution plates out on the immersed metal sheet.

2.3.1.5 Radioactive waste:

The safe management of radioactive waste should ideally be the subject of a proper national strategy with an infrastructure that includes appropriate legislation, competent regulatory and operational organizations, and adequately trained personnel.

Properly calibrated instruments should be available for monitoring dose rates and contamination, and the liquid waste should be collected in suitable containers according to its chemical and radiological characteristics, volume, handling and storage requirements [(4)].

The treatment includes operations intended to improve safety and economy by changing the characteristics of the radioactive waste. The basic objectives are:

- Volume reduction, by evaporation under controlled conditions;
- Removal of radionuclides, by ion exchange;
- Change of composition, by precipitation / filtration [(4)].

The disposal of the radioactive wastewater may be done only within the limits authorized by the regulatory authority, and should take into account subsequent dispersion. All hospitals should ensure that radionuclides are not disposed unless:

- The activity disposed is confirmed to be below the clearance levels;
- The activity of the liquid effluents discharged is within limits authorized by the regulatory authority [(4)].

Any hospitals wishing to dispose radioactive wastewater with activity above the clearance levels should apply for an authorization [(4)]. It should also:

- Keep all radioactive discharges as far below the authorized limits as is reasonably achievable;
- Monitor and record the discharges of radionuclides with sufficient detail and accuracy to demonstrate compliance with the authorized discharge limits;
- Report discharges to the regulatory authority at whatever intervals are specified in the authorization; and
- Report promptly to the regulatory authority any discharges that exceed the authorized limits [(4)].

Whatever radioactivity is discharged within the clearance levels or under authorization, the non-radiological hazards of the discharge must also be considered and the requirements of any regulations governing those hazards should be met [(4)].

WHO recommended many other procedures and regulations for treatment and disposal of the radioactive wastewater, those are:

- Radioactive waste resulting from cleaning-up operations after a spillage or other accident should be retained in suitable containers, unless the activity is clearly low enough to permit immediate discharge. If excessive activity enters the sewers accidentally, a large volume of water should be allowed to flow to provide dilution to about 1 kBq per liter.
- Higher-level radioactive wastewater of relatively short half-life (e.g. from iodine-131 therapy) and liquids that are immiscible with water, such as scintillation counting residues and contaminated oil, should be stored for decay in marked containers, under lead shielding, until activities have reached authorized clearance levels. Water-miscible waste may then be discharged to the sewer system.
- Liquids that are immiscible with water, such as scintillation counting residues, should not be discharged to sewers but treated by an alternative method, e.g. incineration, absorption.
- The drains that serve sinks designated for discharge of radioactive liquids should be identified. If repairs become necessary, radiation levels should be measured as the drain or sewer is opened up, and appropriate precautions should be taken.
- It is not usually necessary to collect and confine patient's excreta after diagnostic procedures, although ordinary toilets used by such patients should

be checked regularly for radioactive contamination by competent staff (e.g. the Radiation Officer). In the case of therapeutic procedures involving radionuclides, hospital toilet must be checked for radioactive contamination after each use by patients, unless every patient has an individual toilet.

2.3.2 Connection to a municipal sewage treatment plant:

According to the WHO guidelines; in countries that do not experience epidemics of enteric disease and that are not endemic for intestinal helminthiasis, it is acceptable to discharge the sewage of hospitals to municipal sewers without pretreatment, provided that the following requirements are met:

- The municipal sewers are connected to efficiently operated sewage treatment plants that ensure at least 95% removal of bacterial;
- The sludge resulting from sewage treatment is subjected to anaerobic digestion, leaving no more than one helminth egg per liter in the digested sludge;
- The waste management system of the hospital maintains high standards ensuring the absence of significant quantities of toxic chemicals, pharmaceuticals, radionuclides, cytotoxic drugs, and antibiotics in the discharged sewage;
- Excreta from patients being treated with cytotoxic drugs may be collected separately and adequately treated (as for other cytotoxic waste) [4].

If these requirements cannot be met the wastewater should be managed and treated as recommended in section (2.3.2) below.

In normal circumstances, the usual secondary bacteriological treatment of sewage, properly applied, complemented by anaerobic digestion of sludge, can be considered as sufficient. During the outbreaks of the enteric disease, however, or during critical period (usually in summertime because of warm weather), effluent disinfection by chlorine dioxide (ClO_2) or by any other efficient disinfectant is recommended by the WHO. If the final effluent is discharged into water bodies, disinfection of the effluent will be required throughout the year [4].

2.3.3 On-site treatment or pretreatment of wastewater:

Efficient on-site treatment of hospital sewage according to WHO the guidelines should include the following operations:

- *Primary treatment*
- *Secondary biological* purification. Most helminths will settle in the sludge resulting from secondary purification, together with 90-95% of bacteria and significant percentage of viruses; the secondary effluent will thus be almost free of helminths, but will still include inactive concentration of bacteria and viruses.
- *Tertiary treatment.* The secondary effluent will probably contain at least 20 mg/liter suspended organic matter, which is too high for efficient chlorine disinfection. It should therefore be subjected to a tertiary treatment, such as rapid sand filtration, which reduces the content of suspended organic matter to less than 10 mg/liter.
- *Chlorine disinfection.* To achieve pathogen concentrations comparable to those found in natural waters, the tertiary effluent will be subjected to chlorine disinfection to the breakpoint [4].

Disinfection of the effluents is particularly important if they are discharged into water bodies close to shellfish habitats, especially if local people are in the habit of eating raw shellfish [4].

2.3.4 Sludge treatment:

According to the WHO guidelines; the sludge from the sewage treatment plant requires anaerobic digestion to ensure thermal elimination of most pathogens. On-site treatment of hospital sewage will produce a sludge that contains high concentrations of helminthes and other pathogens; it may be dried in natural drying beds and then incinerated together with solid infectious hospital waste [22].

2.4 Disposal and reuse of wastewater and sludge:

There is no safe solution for the disposal of sewage from a hospital that cannot afford a compact sewage treatment plant [4]. The public health hazards associated with the land disposal of wastewater effluent include:

1. Possible inhalation of aerosols containing pathogenic microorganisms. Also contact with and ingestion of pathogens in non-disinfected wastewater by workers.
2. Consumption of raw or inadequately cooked vegetables from crops irrigated with wastewater, and the possible ingestion of heavy metals or other toxic materials taken up by crops during growth.
3. Contamination of groundwater through infiltration and percolation of wastewater microorganisms and chemicals into a groundwater aquifer serving as a source of drinking water.
4. Runoff, from land areas receiving wastewater effluent, to surface waters.
5. Possible cross-connection between potable and non-potable waters systems.
6. Build-up of detrimental chemicals in the soil [23].

Wolman [24] has suggested seven constraints which can serve as a model to guide professional judgment in the review of proposals for wastewater disposal by land treatment:

1. Carefully, efficiently, and continuously managed.
2. Appropriate site permeable and porous soil.
3. Hold-over storage for wet weather.
4. Crops not eaten raw.
5. Undue hazard to groundwater or drainage prevented.
6. Potential hygienic risks are detected and controlled.
7. The process is cost-effective.

According to the relevant WHO guidelines the treated wastewater should contain no more than one helminth egg per liter and no more than 1000 faecal coliforms per 100 ml if it is to be used for unrestricted irrigation. It is essential that the treated sludge contains no more than 1000 faecal coliforms per 100 g. The sludge should be applied to fields in trenches and then covered with soil [22].

2.5 Management of hospitals wastewater in Khartoum state:

Literature describing hospitals and laboratories wastewater treatment in Khartoum State is not readily available. But generally it is treated as such as the domestic wastewater, therefore, the hospitals wastewater treatment can be described within the literature describes wastewater treatment in Khartoum State.

In Khartoum State more than 80% of the population are served by the traditional pit latrines (see annex (2.1)), which are closely associated with fly breeding, bad adours, and possible of soil, and ground and sub-surface water [25].

About 10% of the population are served by septic tanks [25] (see annex (2.2)), which are considered a good technology; nevertheless there are a problems of final effluent disposal. The practice in Khartoum State is to dispose of the effluents into the ground close to areas of high population density and areas of high value lands, which could have a drastic effect on ground water quality.

The remaining 10% of the population are served now by, poorly functioning and over loaded municipal sewerage systems [25]. These are:

- El Qoz sewerage treatment plant;
- The Green Belt Relief plant (Soba);
- Khartoum North sewerage treatment plant (El Haj Yousif)

General features of the municipal sewage treatment plants are summarized in table (2.4).

Table (2.4) Features of the sewage treatment plants in Khartoum State

Treatment Plant	Treatment Process	Commissioning Date	Design Capacity(m^3/d)	Remarks
El Qoz	Trickling filter	1959	14500	Stopped
Soba	Stabilisation ponds	1981	31420	Efficiency about 60%
Haj Yousif	Stabilisation ponds	1971	24000	Inefficient operation

The first sewerage treatment plant (El Qoz) was commissioned on November 1959; the plant was intended to serve the area extending from the Blue Nile southward to street No. 61 with a population of about 80,000persons at a rate of 40 gallon per head per day. The design capacity was 3.8 million gallon per day (14,500m^3/day). Immediately after commissioning it was decided to connect the Khartoum New Extension comprising about 1400 plots, which increased the load to 280,000 gallons per day exceeding the original design capacity [25].

The plant was a biological treatment unit based on conventional trickling filters. The treated effluent was supposed to irrigate a 7,000 Fedan Green Belt area established south of Khartoum. At the end; El Qoz Sewage Treatment Plant was overloaded: It was receiving more than three times its designed capacity and almost all of its units were not operating, which means it was providing no treatment, and the collected effluent was by-passed to the Green Belt without treatment or it gravitates to the White Nile during the frequent power cuts [(25)].

In order to remedy this situation a new sewage treatment plant was designed and constructed in 1981. This new plant is situated within the Green Belt and referred to as Soba Plant (Relief Plant).

The Relief Plant is based on stabilization ponds with a design capacity of 31420 m^3/day to relief the old plant through the diversion of excess flow to the plant and to serve new extensions in Khartoum.

The third municipal sewage treatment is situated in Khartoum North (El Haj Yousif Sewage Treatment Plant) to serve the Khartoum North industrial (the largest industrial area in the country) and the residential areas.

According to the records available, this plant should have been executed in three Phases:

- Phase I :To connect the industrial area;
- Phase II :To connect the residential area;
- Phase III: To serve extensions to the industrial and residential areas.

The plant was based on stabilization ponds and the treated effluents should have been disposed of into Kuku Scheme irrigation canal. This has never materialized because of the unacceptable quality of the final effluent being unsuitable for irrigation purposes [(25)]. Unfortunately, only Phase I was completed by 1971 and neither Phase II nor

Phase III were completed due to the practical difficulties. Failure in holding to this schedule and connecting Phase II until now has resulted in the complete failure of the plant and closure in practice by 1981 [25].

From the above review, there is no any hospital in Khartoum North connected to the sewerage system, all of the hospitals there have used on-site treatment system, and in Omdurman City, where there is no sewerage system, all hospitals as such as those in Khartoum North, have used on-site treatment system. But in Khartoum City, where there is a sewerage system, both systems were used, the off-site treatment system in the hospitals that placing in areas covered with the sewerage system, and the on-site treatment system in the other hospitals.

CHAPTER THREE

METHODS & MATERIALS

3.1 Study area:

This study is carried out in Khartoum state, which straddles the confluence of the Blue and White Niles and covers 28,000 km^2 or about 1% of the total area of the Sudan (see annex (3.1)), 95% of it, is rural and 5% is urban [(26)] .On a featureless plain having an average altitude of 380 m (1260ft) above the sea level [(27)]. It extends from latitude 15° 10´N to 16° 30´N placing it in a climatic terms on the southern edge of the desert [(28)], where the monthly evaporation and relative humidity ranges are 14-23mm and 16-49% respectively (1961-1990).

Situated at the southern margin of the desert, Khartoum state experiences a tropical continental type of climate characterized by two temperatures maxima when the sun is over head both in May and October, a short rainy season with total amount of annual rainfall is 164mm (6.56inches), which is apparently lost through evaporation and transpiration, because of excessive heating. Temperatures of 32°c to 38°care common through out the year, with extremes of 47.7°c and 10°c, which are usually recorded in June and December respectively. High temperature and little rainfall have produced a thin cover of vegetation which is even absent over large areas in the vicinity of the urban area.

Climatically, there are four well-marked seasons in the year [(27)]:

1. The winter season from mid-November to March.
2. The summer season from March to mid-July.
3. The rainy season from mid-July to mid-September.
4. A short summer season (Darat) from mid-September to mid-November.

Khartoum state is made up of the three towns; Khartoum, Khartoum North and Omdurman, which are known together as the “tripartite capital”. In case of Khartoum and Khartoum North the plain increases slightly in the height from west to east, where-as Omdurman the land gains in altitude towards the northwest, which is also the highest in the whole urban area. These are the Markhiyat hills that rise between 50 and 56m (164-184 ft) above the general level of the town [(27)]. The underlying geological structure within the urban area is the Nubian sand stone. In Khartoum and Khartoum North, a thick layer of dark heavy Gezira clay covers the Nubian series, which may reach a hundred feet in a thickness, expand when moist and contract when dry, thereby causing a constructional hazard. Omdurman on the other hand, rests on the Nubian sand stone, which is very suited for construction and building purposes. The red sandy soil of Omdurman has a high content of iron stone gravel. However, from agricultural point of view the soil of both Khartoum and Khartoum North are by far more fertile than those of Omdurman. The flat nature of the area has given rise to serious drainage problem, especially at the periphery of the urban area [(29)].

Five bridges link the three towns up. Nevertheless, each has its different characteristics with Khartoum as the political, administrative and modern commercial center of the country with the only “European” style first class residential and shopping area of any size in the country, Khartoum North as the main industrial center, and Omdurman a more traditionally structured Sudanese town with which many Sudanese could more easily relate, it had thus become the residential area for many who found employment in Khartoum state [(26)].

Demographically, Khartoum state has a population of 4,944,742 with annual growth rate 4.04% (1998-2003), 86.34% of the population are urban [(30)],and 1,509,623 of them are in Khartoum, 1,418,985 in Khartoum North, and 2,016,133 in Omdurman[(30)].

The literacy rate is 73.6 % and the growth domestic product (GDP) is 296 U.S. $ per capita (1998) [31].

Today Khartoum state has much more than its fair of modern facilities and non-agricultural employment. Although Khartoum state is served better than anywhere else in the Sudan, in particular medically, there are 10 doctors and 70 nurses for every 100,000 of population and from every 100,000 population there are 41.8 and 5282.7 cases of tuberculosis and malaria respectively and 0.99% of population living with HIV in adulate age (15-49) [31].

Table (3.1) summarized the services situation for safe water, heath service and sanitation for many years in the Sudan.

Table (3.1) Population without access to safe water, health service and sanitation in Sudan with HID rank for the following years

HID Rank	Population without access to			
	Year	Safe water (%)	Health service	Sanitation
142	1999	27	30	49 [31]
157	1998	50	30	78 [32]
144	1995	12.7	13.5	6.5 [33]
151	1994	45	60	70 [34]
158	1993	—	7.8	22.7 [35]

3.2 Study case:

This research had been conducted in two stages; the first stage had been conducted from January to March 2001 to collect information about the existing practices in hospitals for wastewater management as a hazardous waste; the existing practices included practices for collection, treatment, disposal and reuse systems, if any with photo-documentation. The second stage had been conducted from April to August 2001 to collect samples of wastewater from various sources in the hospitals to experiment the characteristics of wastewater including of its properties (COD, BOD, PH, and S.S.).

This information is used to assess the overall status of hospital wastewater management in Sudan to develop outlines guidance to remedy the existing situation.

3.2.1 Wastewater management activities included:

Hospital wastewater management activities included in this research are:

1. Collection systems.
2. Treatment systems.
3. Disposal systems.

3.2.2 Hospitals included:

Hospitals in Khartoum state are broadly classified according to their ownership status as:

1. Federal hospitals; belonging to the Khartoum federal ministry of health.
2. State hospitals; belonging to the Khartoum state ministry of health.
3. Private hospitals; underlying state ministry of health regulations.

Table (3.2) presents Khartoum hospitals categories according to their ownership.

Table (3.2) Number of hospitals and total number of bed in Khartoum state

Hospital category	No. of hospitals	Total No. of beds
Federal hospitals	21	4491 [36]
State hospitals	22	1749 [37]
Private hospitals	50	561 [36]
Total hospitals	93	6801 [36]

Federal and state hospitals are further classified according to their type as in tables (3-3), (3-4) and (3-5).

Table (3-3) Number of state and federal hospitals according to their types

Hospital type	No. of hospitals
Specialist	12
General	33
Total	43

Table (3-4) Number of federal hospitals in Khartoum state according to their sub-categories

Hospital sub-category	No. of hospitals
University	2
Training	3
Armed forces	3
Public	13
Total	21

Table (3-5) Number of Khartoum state hospitals by hospitals types

Hospital type	No. of hospitals
District	13
Sub-district	9
Total	22

3.2.3 Sampling:

This research aims to cover all hospitals categories in Khartoum state with its two types of soil (Nubian sand stone in Omdurman and heavy Gezira clay in both Khartoum and Khartoum North) and the two types of the treatment systems: the on-site treatment system and off-site treatment system.

The studied cases of hospitals were selected as follows:

1. From the three oldest federal hospitals in Khartoum state, two hospitals are selected, Khartoum Training Hospital as the biggest hospital with off-site treatment system, and Khartoum North Training Hospital as the biggest hospital with on-site treatment system in Khartoum North. Both of them are general hospitals;
2. The Military Medical Corporation is selected as the biggest hospital in Sudan (armed forces hospital), which is considered environmentally critical area, because it is waterfront area with on-site treatment system and biggest number of beds in Sudan hospitals;
3. Soba University Hospital is added to the study case, because it is the biggest university hospital in Sudan, and the only hospital using the stabilization ponds as an on-site treatment system, the Central Veterinary Research Laboratories is connected to the stabilization ponds, so it is included in this study;
4. National Center of Isotopes and Radiotherapy is the only source of radioactive wastewater. So it was chosen to study the methods of managing its radioactive wastewater;
5. The National Health Laboratory is added to the study cases, because it is the only central laboratory in Sudan and it contains all types of laboratories;

6. Ibrahim Malik Hospital and Ahmed Gasim hospital are selected as the two biggest state-district hospitals, the first one as general hospital, and the second as specialized hospital, it consists of two hospitals; Ahmed Gasim Cardiac and Renal Transplantation, and Ahmed Gasim Pediatrics Specialized Hospital, they have one on-site treatment system, so they were considered as one hospital;
7. Ibn Khaldoon Hospital was selected randomly as a private hospital.

Table (3-6) List of studied hospitals in this research

Name of Hospital	**Hospital Location**	**Hospital Category**	**Hospital Sub-category**	**Hospital Type**	**No. of Bed**
Khartoum Training Hospital	Khartoum	Federal	Training	General	765
Khartoum North Training Hospital	Khartoum North	Federal	Training	General	423
Military Medical Corporation	Omdurman	Federal	Armed Forces	General	1057
Soba University Hospital	Khartoum	Federal	University	General	420
National Center of Isotopes &Radiotherapy	Khartoum	Federal	Public	Special-ized	92
Ahmed Gasim Hospital	Khartoum North	State	Sub-District	Special-ized	185
Ibrahim Malik Hospital	Khartoum	State	Sub-District	General	251
Ibn Khaldoon Hospital	Khartoum	Private	-	General	32
National Health Lab.	Khartoum	Federal	-	General	-
Total No. of bed					3225

All hospitals in Khartoum state are illustrated as in annex (3.2)

3.3 Questionnaire:

To identify where problems remain and what simple practical actions should be taken to solve them, a questionnaire was designed by the researcher (see annex (3.3)); it includes tables to be filled, explanation questions to be answered and dimensions to be measured; it is divided as follows:

- Questionnaire 1: includes general information and types of wastewater management
- Questionnaire 2: includes practices of collection system.
- Questionnaire 3: includes practices of on-site treatment system.
- Questionnaire 4: includes x-ray unit, all types of laboratories and their wastewater management practices.

3.4 Methodology:

Methods used in this research are as follows:

3.4.1 Gathering of information:

There are two types of information gathered: statistical data and general information on the hospitals wastewater management.

3.4.1.1 Gathering of statistical data:

There are three main sources of the statistical data:

1. Federal ministry of health;
2. State ministry of health;
3. The statistical departments in each of the studied hospitals.

3.4.1.2 Gathering of general information on the hospitals wastewater management:

In gathering the general information the following tasks were done during the field survey:

1. Interviews of wastewater management staffs in the studied hospitals;
2. Visual survey of collection and on-site treatment systems in the studied hospitals

3. Measuring volumes of the on-site treatment systems.

3.4.2 Estimating quantities of water consumed and wastewater produced:

3.4.2.1 Water consumption:

1. The actual water consumption: there are no water-meters in the studied hospitals, and no accurate figures were found for the actual consumption. Therefore different method was used for each hospital.
2. The estimated water consumption: the estimated water consumption was calculated as follows:
   1. Water consumption per day is 300 l/b. d. [15] (see section (2.2.1)).
   2. From the working experiences:
      - Co-patient consumes 50 l/d.
      - Out-patient consumes 5-10 l/d.
      - Staff consumes 10-20 l/d.
      - Reside sister and doctor consumes 150 l/d.
   3. The estimated water consumption per day is calculated as follows: *300 l/b.d. x No. of bed + 5 l/d. x No. of out patient + 10 l/d. x No. of staff + 150 l/d. x capacity of sisters and doctors houses*
   4. The estimated water consumption per bed per day is calculated as follows: *The estimated water consumption per day / No. of bed*

3.4.2.2 Wastewater produced:

John Pickford assumed that 90% of the water supply contributing to the sewers, from this assumption the actual and the estimated wastewaters produced is calculated as follows:

1. *The actual wastewater produced = 0.9 x actual water consumption*
2. *The estimated wastewater produced = 0.9 x estimated water consumption*

3.4.3 Assessing methods used for on-site treatment systems:

3.4.3.1Grease traps:

Steps used are as follows:

1. Average range of wastewater flow per meal is 8-15 l, and the typical average is 10 l/meal (15).
2. Wastewater flows from the hospital's kitchen was calculated as follows:

   10 l/meal x 3 meal/d. x No. of bed = 30 l/d x No. of bed
3. Retention time for grease trap is 10 min., so volume needed is calculated as follows:

   Flow rate (m^3/d) x 10 min. / 60 (min/hr) x 24 (hr/d) = flow rate (m^3)/ 6 x 24
4. Actual volume (the existing volume)of grease trap is calculated as follows:

   (Liquid depth (h_l) x width (b) x length (l)) m^3
5. The volumetric efficiency is calculated as follows:

   Actual volume / volume needed x 100%

3.4.3.2 Septic tanks and seepage pits:

Assume that wastewaters uniformly distributed between septic tanks. The steps are as follows:

1. *Effective volume = (length (l) x width (b) x water depth (h_l)) m^3*
2. *Total effective volume = Σ (length (l) x width (b) x water depth (h_l)) m^3*
3. *Wastewater flow rate = No. of bed x wastewater produced l/bed)/ 1000 (l/ m^3)*
4. *Volume needed of septic tanks = 3 x wastewater flow rate (m^3)*
5. *Retention time = Actual volume of septic tanks / Wastewater flow rate (day);*
6. *Volumetric efficiency =*

   (Actual volume of septic tanks / Volume needed of septic tanks) x 100%

7. From Khartoum sanitation report seepage pits of 2.5 diameter at their excellent performance percolate 18 m^3/day, therefore:

   Percolation capacity for seepage pit of 2.0 m diameter $= 18 \times 2 / 2.5\ m^3/day$

   Percolation capacity for seepage pit of 1.5 m diameter $= 18 \times 1.5 / 2.5\ m^3/day$

   Actual percolation capacity $= \Sigma$ *No. of pit x percolation capacity*

8. Percolation capacity needed = wastewater flow rate m^3/day;

9. *Volumetric percolation efficiency =*

   Actual percolation capacity / Percolation capacity needed x 100%

3.4.3.3 Filters:

It is known that for each 20 persons (3.0 m^3), there is 1.0 m^3 of gravel is needed with depth of first layer (3-6 mm) 10-15 cm, and with depth of second layer (12-18mm) 40-65cm [38].

Volume of filtration = filtration area x filter depth

3.4.4 Estimating types and quantities of pollutants discharged from laboratories:

- From the literature review all types of pollutants discharged from all types of laboratories are delimitated.
- And from the field survey types of laboratories in each hospital are also delimitated.
- From the two above steps types of pollutants discharged from each studied hospital are delimitated.
- Also from the literature review the two pollutants of biggest quantities more discharged from laboratories are estimated. The two pollutants are sodium cyanide, which is used in heaematology lab. In hemoglobin blood (H.B.) test, and picric acid, which is used in chemical pathology Lab., in creatinine test (renal function). For each of them special method had been used.

3.4.4.1 Method used to estimate quantities of sodium cyanide (NaCN) discharged to the hospitals sewers:

The steps used for the estimation are as follows:

1. Total number of samples of H.B. test per month are estimated for each hospital from the statistics department;
2. The Drabkin solution which used in this test is prepared by dissolving 50mg of NaCN, 200mg of KFeCN and 140mg of KH_2PO_4 in one liter of distilled water[39];
3. For any liter of Dabkin solution, there are 100ml are used as a blank, and for any sample only 4-5ml are used, and approximately about 50% of NaCN react, for this, the quantity of NaCN discharged monthly to the hospitals sewers are estimated as follows:

   (No. of sample / month x 5ml x I l / 1000 + 0.1 l x No. of sample / month x 5ml x I l / 1000) x 50 mg / l x 0.5
4. From the above quantities of NaCN discharged monthly to the hospitals sewers are estimated;

By using the same procedure, quantity of NaCN discharged monthly and annually from all hospitals in Khartoum state to the hospitals sewers is estimated.

3.4.4.2 Method used to estimate quantity of picric acid discharged to the hospitals sewers:

The steps used for the estimation are as follows:

1. Total number of samples per month of creatinine test are estimated for each hospital from the statistics departments,
2. Creatinine reagent, which used in this test, is prepared by dissolving 9.12 g of picric acid and a color developer in one liter of distilled water [39].

3. For any sample only 1ml is used and about 50% of it react, for this, the quantity of picric acid discharged monthly to the hospital sewers is estimated as follows:

   (No. sample / month x 9.12 g/l x 1000 mg/g x 1 ml x 1 /1000 l/ml x 0.5)

4. From the above the quantities of picric acid discharged to the studied hospital Sewers are estimated.

By using the same procedure the quantities of picric acid discharged monthly and annually from all hospitals in Khartoum state are estimated.

3.4.5 Estimating quantities of silver-recovable discharged from x-ray units:

In the x-ray unit, there are two main sources of such silver as is recovable, those are [21]:

1. Exhausted processing solutions.
2. Discarded film materials and photographic paper.

It is believed by those who are used to process medical x-ray films that the amount of silver recovable potentially are 3000 to 6000grams for every 1000 square meters of film processed; and that every kilogram of discarded radiographs (exposed and processed films) could yield from 6.4 to 25.5 grams according to the efficiency of the recovery system, the recovering apparatus and the type of film used [21].

There are four types of films used:

- Type A (38cm x 30cm), for adult.
- Type B (15cm x 12cm), for children.
- Type C (10cm x 8cm), for small organs.
- Type D (7cm x 7cm), for teeth.

Steps used to estimate quantities of silver-recovable discharged to hospitals sewers are as follows:

1. The total area of films used is estimated for each hospital by *Σ (No. of films used x area of film type)*
2. The total area of films used in all studied hospitals is estimated;
3. For each 1000m^2 of film used, there are 3000 to 6000 grams of silver-recovable, and from the total area, total amount of silver-recovable is estimated for each hospital, and then for all studied hospitals;
4. From the annual medical reports of state and federal ministries of health, and by using the same method, total amount of silver-recovable from all hospitals in Khartoum state is estimated for year 2000and 2001;
5. Percentage amount of silver-recovable discharged to public sewers is estimated as follows:

   (Total area of films used in studied hospitals with off-site treatment system/ Total area of films used in all studied hospitals) x 100%
6. Percentage amount of silver-recovable discharged to seepage pits and other is estimated as follows:

   (Total area of films used in studied hospitals with on-site treatment system/ Total area of films used in all studied hospitals) x 100%
7. Percentage amount of silver-recovable from all studied hospitals to that recovable from all hospitals in Khartoum state is estimated as follows : *(Total area of films used in all studied hospitals/ Total area of films used in all studied hospitals) x 100%*
8. From old experienced technicians, every 30 liters of fixer solution can fixe from22 to 26 square meter of x-ray film (according to their type), so mean area can give from 0.072 to 0.144 kg, for this the concentration of silver-recovable

discharged to the hospitals sewers is estimated as follows: (*Amount of silver-recovable from* $(24m^2)$ *kg / 30l x* 10^6 *mg/kg)*

3.4.6 Determining characteristics of hospitals wastewaters:

Determining the characteristics of hospitals wastewaters includes of the following properties:

- pH, using digital pH meter;
- Chemical Oxygen Demand (COD), using open flask method;
- Biological Oxygen Demand (BOD), using digital track;
- Suspended Solids (S.S.)

It known that, any area in the hospital has its own wastewater characteristics. The following areas were selected to give general idea about the characteristics of the hospitals wastewaters:

- Laboratories;
- X-ray unit;
- Laundry;
- Patient-care areas;
- Final effluent from all areas in the hospital.

Hospitals included in this section are:

1. Khartoum Training Hospital: sample of wastewater was taken from the last manhole;
2. Khartoum North Training Hospital: samples of wastewater were taken from the x-ray unit and laboratories.
3. Military Medical Corporation: samples of wastewater were taken from the central laboratory, laundry, wetland, patient-care areas (referred clinic, casuality, and Families hospital), and the Nile River (In flood season Nile

River covers the final disposal area (surface area), so Nile River was included as a final disposal option).

4. Soba University Hospital: samples were taken from the anaerobic, facultative and maturation ponds.
5. National Health Laboratory: sample of wastewater was taken from the last manhole.

3.4.7 Computer programs used:

1. AutoCAD 2000 : To draw the detail types of the existing septic tanks, grease traps, and figures.
2. Adobe Photoshop 6.0 : To minimize the space of the photos from the total capacity of the hard disk.
3. CorelDraw 10 : To design the pages that present photos, and annotations.
4. Visual Basic 6.0 : To make the program that designs septic tanks to the hospitals according to the different data.

CHAPTER FOUR

RESULTS & DISCUSSIONS

4.1 General statistical data:

Data were collected from the following cases study:

1. Khartoum Training Hospital;
2. Khartoum North Training Hospital;
3. Military Medical Corporation;
4. Soba University Hospital, and Central Veterinary Research Laboratories;
5. National Center of Isotopes & Radiotherapy;
6. Ibrahim Malik Hospital;
7. Ahmed Gasim Hospital;
8. Ibn Khaldoon Hospital;
9. National Health Laboratory.

The collected data includes:

1. No. of bed;
2. Bed occupancy;
3. No. of out patient per day;
4. No. of employees;
5. No. of employees per day; and
6. Capacity of sisters and doctors house.

The collected statistical data is listed in table (4.1).

Table (4.1) Collected statistical data from studied hospitals

Name o f Hospital	No of beds	Bed occ. (%)	No. of out-patients per day	No. of employees	No. of employees per bed	Capacity of sisters&doctors houses(sis. or doc.)
Khartoum Training Hospital	765	80.2	285	2090	2.37	80
Khartoum North Training Hospital	444	53	332	1530	1.81	125
Military Medical Corporation	1057	69	680	2329	2.2	64
Soba University Hospital	450	62	154	1400	3.1	–
Central Veterinary Research Laboratories	–	–	–	506	–	–
National Center of Isotopes & Radiotherapy	92	90.45	20	303	3.3	–
Ibrahim Malik Hospital	251	80	30	726	2.9	–
Ahmed Gasim Hospital	185	58.33	33	591	3.2	30
Ibn Khaldoon Hospital	32	39.8	30	120	3.75	–
National Health Laboratory	–	–	–	512	–	–

4.2 Water and wastewater flow rates:

As shown in table (4.2) no water – meters were used, so the actual water consumption ($Q_{s\ (cal)}$) can not be calculated directly, therefore different method was used for each hospital, but only one method was used to calculate the estimated (theoretically) water consumption ($Q_{s\ (est.)}$) (see section (3.4.2)).

Actual wastewater produced ($Q_{w\ (cal)}$) was calculated only for two hospitals; those are

1. Military Medical Corporation: wastewaters are pumped 15 times per day by tanker with a capacity of 3000 gallons, and two seepage pits with a diameter of 2.5m works as good as can.
2. Soba University Hospital: pump of wastewater is worked for 4.25 hr / day with a capacity of 36 m^3/ hr. And pump of Central Veterinary Research Laboratories is worked for 3 hr/ day with a capacity of 16 m^3/ hr.

Estimated wastewaters ($Q_{w\ (est.)}$) for all hospitals were calculated by methods in section (3.4.2) in table (4.3).

Table (4.2) Water consumption (Q_s(cal)) & (Q_s(est)) in the studied hospitals:

Name o f Hospital	Source o f water supply	Q_s (cal) m^3/d	Q_s (cal) l/bed.d	Q_s (est) M^3/d	Q_s (est) l/bed.d	Remarks
Khartoum Training Hospital	G.water& mun. net	—	—	302	395	Endless and unknown water lines without water-meter ($81m^3$ from groundwater).
Khartoum North Training Hospital	G.water& mun. net	—	—	191	430	Endless and unknown water lines without water-meter and intermittent pumping from ground water.
Military Medical Corporation	Municipal net	—	—	406	384	A lot of leaky pipes and faucets and no water-meter
Soba University Hospital Central Veterinary Research Laboratories	Ground water	169.78 53	377.29 —	172 —	383 —	High pressure in the water supply pipes without water-meter and intermittent pumping to the elevated tank
National Center of Isotopes & Radiotherapy	Municipal net	29	315	35	384	Many leaky faucets and no water-meter
Ibrahim Malik Hospital	Ground water	47.25	188	95	380	Water supply well is far from the laboratories seepage pit with less than 50 m
Ahmed Gasim Hospital	Municipal net	—	—	71	383	Many water supply lines without water-meter
Ibn Khaldoon Hospital	Municipal net	12	375	12.55	392	High pressure in the water supply pipes without water-meter
National Health Lab.	Municipal net	—	—	10.24	—	—

Table (4.3) Wastewater produced in the studied hospitals Q_w (cal) & Q_w (est)

Name o f Hospital	Q_w (cal) m^3/d	Q_w (cal) l/bed.d	Q_w (est) m^3/d	Q_w (est) l/bed.d
Khartoum Training Hospital	—	—	272	355
Khartoum North Training Hospital	—	—	172	387
Military Medical Corporation	206	195	365	345
Soba University Hospital	153	340	155	344
Central Veterinary Research Laboratories	48	—	—	—
National Center of Isotopes & Radiotherapy	—	—	31.5	342
Ibrahim Malik Hospital	—	—	85.5	340
Ahmed Gasim Hospital	—	—	64	345
Ibn Khaldoon Hospital	—	—	11.3	353
National Health Laboratory	—	—	9.22	—

4.3 Review of the existing sanitation practices:

As shown in table (4.4), there are 4 hospitals with off-site treatment system, and 5 hospitals with on-site treatment system. Existing practices sanitation are reviewed firstly to that hospitals with off-site treatment system, and then to that of on-site treatment systems.

Onsite collection systems are reviewed by photos for both types of hospitals.

4.3.1 Existing sanitation practices in hospitals with off-site treatment system:

The four hospitals are in Khartoum, and all of them are connected to the Khartoum net work without any pretreatment and have the same problem; that last manhole always surcharges (see plate (4)).

1. **Khartoum Training Hospital**

It is mainly suffer from the incorrect and badly use of sanitary facilities and the lack of maintenance (see plates (1), (2), and (3)).

2. **National Center of Isotopes& Radiotherapy**

- Urine from patient treated with radiation is collected in plastic container and stored for 3 days then discharged to sewers.
- Wastewater is collected from different storeys through down pipes near potable water pipes (see plates (5), (6), and (7)).
- In the ground floor, gray wastewater is collected through open channel and then pumped to the sewers (see plates (8) and (9)).

3. **National Health Laboratory**

From different stories of the building, wastewater is collected through iron down pipes and then discharged to the sewers net work.

4. **Ibn Khaldoon Hospital**

Has a proper inside connection system (see plates (10) and (11)).

Table (4.4) Existing sanitation practices in the studied hospitals

Name o f Hospital	Type of treatment	Final disposal	Type of reuse
Khartoum Training Hospital	Off-site treatment (municipal net)	Evaporation	Irrigation
Khartoum North Training Hospital	On-site treatment (septic tank)	Land-based (seepage pit)	—
Military Medical Corporation	On-site treatment (septic tanks ,wetland)	Land-based(soakaway pit ,seepage pit, and surface disposal) , water environment, and Evaporation	—
Soba University Hospital & Central Veterinary Research Laboratories	Off-site treatment (stabilization ponds)	Evaporation	—
National Center of Isotopes & Radiotherapy	Off-site treatment (municipal net)	Evaporation	Irrigation
Ibrahim Malik Hospital	On-site treatment (septic tank)	Land-based (seepage pit)	—
Ahmed Gasim Hospital	On-site treatment (septic tank)	Land-based (seepage pit)	—
Ibn Khaldoon Hospital	Off-site treatment (municipal net)	Evaporation	Irrigation
National Health Laboratory	Off-site treatment (municipal net)	Evaporation	Irrigation

4.3.2 Existing sanitation practices in hospitals with on-site treatment system:

1. Khartoum North Training Hospital

- Wastewater is treated by 20 septic tanks, table (4.5) gives their details and table (4.14) gives their volumetric efficiency;
- There are 2 common types; F and G ;
- They are desludged every 1 to 3 years in opened pit;
- Laboratories wastewater is disposed through an interceptor and then discharged to seepage pit number11 (men surgical ward);
- Wastewater from septic tanks is disposed via 19 seepage pits, table (4.6) gives their details and table (4.15) gives their percolation efficiency;
- Because of the incorrect design of septic tanks 16 of them are clogged and only 3 are working, those are of number 1, 5, 7;
- Surcharged clogged pits are pumped to those 3 worked seepage pits or to tanker and then disposed in the first manhole of Khartoum North sewerage net work.

See plates (13), (14), and (15)

Table (4.5) Details of Khartoum North Training Hospital septic tanks

No. of S. T.	Name of served area	Total Depth(h) m	Liquid depth (hl)m	Width (b)m	Length (l)m	Detail Type
1	Doctors cafeteria	2.7	2	2	3.5	F
2	Obstrics+Pediatrics Wards (1)	2.3	1.2	2	3.5	F
3	Obstrics+Pediatrics Wards (2)	2.3	1	1	2	G
4	Kitchen+Mosque+Store	2.5	1	1.5	3.5	F
5	Mosque+store	2.5	1.5	3	5	F
6	Women surgical ward	2.5	1.7	3.5	6	F
7	Dilevery theater+personnel	2.5	1.5	1.5	3.5	F
8	X-ray+eyes+bone wards	1.8	1	1	3.5	F
9	Nursing school+ENT ward	2.5	1.8	2	5	F
10	Men medical ward	2.3	1.3	3	6	F
11	Theater+men surgical ward	2.7	1.8	3	6	F
12	Pharmacy+eyes and dental clinics+doctors rest house	2.5	1.5	2	5	F
13	Blood bank+reffered clinic	2	1.2	2	3.5	F
14	Special ward (west)	2.5	1.7	2.5	4.5	F
15	Special ward (north east)	2	1.2	1	3.5	F
16	Special ward (south east)	1.5	0.7	1.25	2	G
17	Male doctors house	2	1.2	2	4	F
18	Male doctors house	2	1.2	2	4	F
19	Female doctors house	2	1.2	1.25	3.5	F
20	Sisters house	2	1.2	2	3.5	F

Table (4.6) Details of Khartoum North Training Hospital seepage pits

No. of Seepage pit	Diameter (m)	Total Depth(m)	Water Depth (m)
1	2	10	6
2	2	10	9
3	1.5	10	9
4	3	11	8
5	2	10	6.5
6	2	10	9.5
7	2	11	7
8	1.5	10	9
9	2.5	10	9
10	3	10	9.5
11	2.5	10	9
12	2	11	9
13	2	10	9
14	2	11	10
15	2	11	9
16	2	10	8
17	2	10	8
18	1.5	10	8
19	1.5	10	8

2. **Military Medical Corporation**

- Due to the incorrect design and connection, there are chronic problems in this hospital, particularly in Baddi ward and casuality. In Baddi ward because of incorrect connection of drain floor (see plates (18) and (19)), and in casuality because of incorrect design and connection of down pipes (see plate (16)). Almost every manhole line has at least one manhole with inverse slope (see plate (21)).
- Wastewater is primarily treated by 25 septic tanks; their details are in table (4.7) and their efficiency is in table (4.14)
    - The first two septic tanks are very old;
    - Septic tanks 10 and 23 are not desludged before;
    - Septic tank 25 is desludged every 3 months;
    - Septic tank 9 is pumped every 3 days;
    - Septic tank 24 is pumped daily;
    - Septic tank 8 and 16 are new and have inlet and out let tees;
    - Septic tank 20and 22 are of low loading, therefore they not desludging;
    - Septic tank14 is connected with seepage pit of septic tank 17.
- Wastewater from septic tanks is disposed to 21 seepage pits and 3 soakaway pits (see plate (22), their details and percolation efficiency are in tables (4.8), and (4.16) respectively;
- The last three septic tank are connected to the soakaway pits;
    - The first is connected with septic tank 23, which is used only by the commander in chief;
    - The second is connected with septic tank 24, which I pumped daily;
    - The third is connected with septic tank 25, which its broken bricks are changed every 2 years.

- Seepage pits, their details and efficiency are in tables (4.8), and (4.15) respectively
    - Seepage pits 1and 2, although they are very old, they work well;
    - Seepage pits 4, 7, 9, 15, and 18are pumped every day;
    - Seepage pits 3, 5, and 6are pumped every 1 to 3 days;
    - Seepage pits 8, 15 are new and not pumped before;
    - Seepage pits 10, and 11 are clogged, the first is conducted to surface area between Nile River and casuality, which is covered totally by water in flood season. The second is conducted to wetland, which ended in the same surface area,
    - Seepage pit 19 is conducted to surface area in front of corporation entrance;
    - Seepage pit 20 is conducted directly to the wetland;
    - Seepage pits 12, and 14 are not reached water table, they are woke as cesspools.
- Wetland (natural wetland): everyday there are 15 tankers of wastewater are discharged on it (see plates (23) and (24)). Its end is covered with Nile water every flood season (see plates (25), (26)).

Table (4.7) Details of Military Medical Corporation septic tanks

No. of S. T.	Name of served area	Total Depth(h) m	Liquid depth (h_l)m	Width (b) m	Length (l) m	Detail Type
1	Baddi ward(west) (ENT)	2.5	1.5	2	5	F
2	Baddi ward(east) (ENT)	2.5	1.5	2	5	F
3	Al-Shallali ward(medical)	2	1	2	5	F
4	Surgery+lundary	2.5	1.5	2	5	F
5	Surgery+doctors&sisters house	2.5	1.5	3	7	F
6	Doctors and sisters house	2	1	2	6	F
7	Intensive care	2.5	1.5	1.5	5	F
8	Skin ward	2.5	1.5	2	5	F
9	Psychiatric ward	2.5	1.5	2	4	F
10	Casuality (north)	2.5	1.5	2	5	F
11	Casuality (south)	2.5	1.5	2	5	A
12	Central laboratory	2.5	1.5	2	3	F
13	Vacating	1.5	0.6	1.5	2	C
14	Nutrition unit	1.5	0.6	1	2	C
15	Officer's families ward	2	1	2	5	F
16	Special ward	3	2	2	6	F
17	Bone surgery	3.5	2.5	3	6	F
18	Refferred clinic	2.5	1.5	1.5	4	F
19	Refferred clinic	2.5	1.5	1.5	4	F
20	Families hospital	2.5	1.5	2	6	F
21	Delivery theater	3	2	2	3	F
22	Pediatrics ward	3	2	2	3	F
23	Commander in chief	2	1	2	2	C
24	Administration	2.5	1.5	2	3	F
25	Maintenance +national medical commission	3	2	2	3	F

Table (4.8) Details of Military Medical Corporation seepage pits

No. of Seepage pit	Diameter (m)	Total Depth(m)	Water Depth (m)
1	1.5	30	15
2	1.5	30	15
3	1.5	28	23
4	2	25	24.5
5	1.5	28	25
6	1.5	28	20
7	2	28	22
8	2	18	
9	2	25	20
10	2	23	22
11	2	35	23
12	2	35	
13	2.5	30	
14	2	25	25
15	2.5	30	20
16	2.5	25	35
17	2	37	37
18	2	37	37
19	2	39	37
20	2.5	30	5
21	2.5	30	5

3. **Soba University Hospital**

- It is the only hospital used centralized on-site treatment system;
- Wastewater is collected from hospital to pump station in the end of the hospital, which pumped to stabilization ponds out of the hospital;
- Details of these stabilization ponds are listed in table (4.9), see plates(27), (28), (29), (30), and (31);
- Facultative ponds are full with grasses and many shepherd bring their cows and goats to eat and drink there;
- There are foaming in the Maturation ponds.

Table (4.9) Details of Soba stabilization ponds

Name of unit	No. of unit	L (m)	b (m)	h_l(m)	D (m)	Volume (m^3)	R.T. (d)	$R.T_n$. (d)
Anaerobic pond	2			6	8	301.59	1.5	1-5
Maturation pond	3	40	40	1.5		7200	36	7-50
Facultative pond	4	50	50	1		10000	50	3-10
Total	9					17501.59	87.5	11-65

4. Irahim Malik Hospital

- Collected wastewater is treated by 7 septic tanks all of detail type (E). There details and efficiency are in tables (4.10) and (4.14) respectively;
- Septic tanks 4, which is served laboratories, no decomposition is seen in it;
- The 7 septic tanks are desludged every 1 to 2 years; and
- septic tanks 6 and 7 are built near together with one slap cover, now they are looking excessive deflected (see plate (34));
- There are the 7 seepage pits in good condition work, there details and percolation efficiency are in tables (4.11) and (4.15) respectively;
- Seepage pit 4, which disposes wastewater of the laboratories, is far from the water supply well with less than 50 m.

See plates (32) and (34)

Table (4.10) Details of Ibrahim Malik Hospital septic tanks

No. of S. T.	Total Depth (h)m	Liquid depth (h_l)m	Width (b) m	Length (l) m	Detail Type
1	2	1.2	2.5	4	E
2	2	1.2	2.5	4	E
3	2	1.2	2.5	4	E
4	2.5	1.5	2.5	4	E
5	2.5	1.5	2	4.5	E
6	2.5	1.5	2	4.5	E
7	2	1.2	2	4	E

Table (4.11) Details of Ibrahim Malik Hospital seepage pits

No. of Seepage pit	Diameter (m)	Total Depth (m)	Water Depth (m)
1	2	14	8
2	2	14	8
3	2	14	7.5
4	2	14	9
5	2	14	7
6	2	14	7.5
7	2	14	8.5

5. Ahmed Gasim Hospital

- Collected wastewater is treated by 9 septic tanks of type A, B, C, and D. All of them have inlet and outlet tees except the last one, which is uncommon design (see annex (3.3)). Their details and efficiency are in tables (4.12) and (4.14) respectively.
- They are desludged every 1 to 3 years in opened pit and then covered with soil.
- The treated wastewater is disposed then to 9 seepage pits; all of them are clogged except seepage pit 6. Their details and efficiency are in tables (4.13) and (4.15) respectively.
- Surcharged pits are pumped to tanker, which disposed it in the first manhole of Khartoum North net work.

(See plates (35), (36), (37), and (38))

Table (4.12) Details of Ahmed Gasim Hospital septic tanks

No. of S. T.	Total Depth(h) m	Liquid depth (h_l) m	Width (b) m	Length (l) m	Detail Type
1	2.5	1.5	2	4	A
2	2.5	1.5	2	4	A
3	1.5	0.7	1	2	B
4	2.5	1.7	2	4	A
5	2.5	1.5	2	4	A
6	2.5	1.5	2	4	A
7	2	1	1	4	C
8	2.5	1.5	2	2	A
9				4	D

Table (4.13) Details of Ahmed Gasim Hospital seepage pits

No. of Seepage pit	Diameter (m)	Total Depth(m)	Water Depth (m)
1	1.5	12	11
2	1.5	12	9.5
3	1.5	12	10.8
4	1.5	12	11
5	1.5	12	11.95
6	1.5	12	8
7	1.5	12	11.7
8	1.5	12	11
9	1.5	12	11

4.3.3 Results of septic tanks and seepage pits:

Results of septic tanks and seepage pits were listed in tables (4.14) and (4.15) respectively (see section (3.4.3.2)).

Table (4.14) Efficiency of septic tanks

Name of Hospital	Actual Volume (Va) m^3	Volume Needed (Vn) m^3	Retension Time (T) day	Volumetric Efficiency (%)
Khartoum North Training Hospital	254.35	516	1.48	49.3
Military Medical Corporation	340.75	1095	.93	31
Ahmed Gasim Hospital	130	166.5	2.34	78
Ibrahim Malik Hospital	90	256.5	1.05	35

Table (4.15) Efficiency of seepage pits

Name of Hospital	Actual Percolation Capacity m^3	Percolation Capacity Needed m^3	Volumetric Efficiency (%)
Khartoum North Training Hospital	259.2	172	150.7
Military Medical Corporation	302.4	365	83
Ahmed Gasim Hospital	97.2	55.5	175
Ibrahim Malik Hospital	100.8	85.5	118

4.3.4 Results of grease traps:

There are only 4 hospitals having grease traps, those are:

1. Khartoum North Training Hospital;
2. Military Medical Corporation;
3. Soba University Hospital; and
4. Ahmed Gasim Hospital.

Their details and efficiency are listed in tables (4.16) and (4.17) respectively.

Although all grease traps have a volumetric efficiency more than 100%, only those of Khartoum North Training Hospital and Soba University Hospital are of correct design.

See plates (39) and (40).

Table (4.16) Details data of grease traps

Name o f Hospital	No. of G.T.	Total depth (h) m	Liquid depth (h_l) m	Width (b) m	Length (l) m	Detail type	Remark
Khartoum North Training Hospital	1	0.5	0.3	0.5	1.0	C	Desludged every 4months
Military Medical Corporation	1	0.5	0.3	0.5	1.5	C	Has a broken cover
Soba University Hospital	2	0.6 0.6	0.4 0.4	0.6 0.6	2.4 2.4	D D	Desludged every 3months
Ahmed Gasim Hospital	2	2 1.5	1.5 1.3	1 1.5	1.0 1.5	A B	(A): flooded and works as a holding tank

Table (4.17) Efficiency of grease traps

Name o f Hospital	Flow rate m^3/d	Actual volume m^3	Volume needed m^3	Volumetric Efficiency (%)
Khartoum North Training Hospital	12.69	0.15	0.088	170
Military Medical Corporation	31.71	0.225	0.22	102
Soba University Hospital	13.5	0.576	0.094	612
Ahmed Gasim Hospital	5.55	4.425	0.04	11062.5

4.4 Results of Laboratories:

There are 5 common laboratories (haematology, chemical, pathology, microbiology, histopathology, and immunodiagnosis), in addition to one or more general (casuality) laboratory in each hospital consist of haematology, chemical pathology, and microbiology laboratories.

Also there are many different uncommon laboratories; those are:

- Research diagnostic laboratory in Khartoum Training Hospital; it is a mechanized laboratory and all reagent used in it is bought up in Kitts;
- Hormones laboratory and Hot laboratory (for Iodine preparation and injection) in National Center of Isotopes & Radiotherapy;
- Parasitology laboratory in Ahmed Gasim Hospital;
- In National Health Laboratory there are 4 uncommon laboratories; those are:
    1. Parasitology laboratory;
    2. Medical Insect laboratory;
    3. External laboratory for Malaria and
    4. Chemical laboratory for dyes production and quality control.

Table (4.18) includes types of laboratories in the studied hospitals, and table (4.19) summarized all types of pollutants discharged to the hospitals sewers from all laboratories in the studied hospital.

Pollutants of biggest quantities are sodium cyanide and picric acid. The first one discharged from haematology laboratory in hemoglobin blood test (H.B.), which is the more use, table (4.20) gives quantities of NaCN discharged to the hospitals sewers. The second pollutant discharged from chemical pathology laboratory in Creatinine test is a phenolic compound, the quantities discharged to the hospitals sewers are as in table (4.21).

See plates (41), (42), and (43)

Table (4.18) Type of laboratories in the studied hospitals

Name o f Hospital	Type of Laboratories						
	Heam.	Chem.	Micro.	Histo.	Imm.	Cas.	Others
Khartoum Training Hospital						2	Research Diagnostic Laboratory
Khartoum North Training Hospital						2	
Military Medical Corporation							
Soba University Hospital							
National Center of Isotopes & Radiotherapy							Hormones Laboratory &Hot Laboratory
Ibrahim Malik Hospital							
Ahmed Gasim Hospital							
Ibn Khaldoon Hospital							
National Health Laboratory							Parasitology, Chemicals, Medical Insects

Legend

Existing

Not existing

Table (4.19) Types of pollutants discharged from all laboratories in the studied hospitals

Name o f Hospital	Type of Pollutants	Final Disposal
Khartoum Training Hospital	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc.	Hospital sewers
Khartoum North Training Hospital	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc, formaldehyde, glutaraldehyde, xylene, alcohols.	Hospital sewers
Military Medical Corporation	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc, formaldehyde, glutaraldehyde, xylene, alcohols.	Hospital sewers
Soba University Hospital	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc, formaldehyde, glutaraldehyde, xylene, alcohols.	Hospital sewers
National Center of Isotopes & Radiotherapy	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc, methanol.	Hospital sewers
Ibrahim Malik Hospital	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc.	Hospital sewers
Ahmed Gasim Hospital	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc.	Hospital sewers
Ibn Khaldoon Hospital	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc.	Hospital sewers
National Health Laboratory	Cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, zinc, formaldehyde, glutaraldehyde, xylene, alcohols.	Hospital sewers

Table (4.20) Quantities of sodium cyanide (NaCN) discharged from studied hospitals

Name o f Hospital	No. of H.B. test/month	No. of H.B. test/year	Q. of NaCN mg/ month	Q. of NaCN mg/ year
Khartoum Training Hospital	4895		673.06	8076.75
Khartoum North Training Hospital	1720		236.5	2838
Military Medical Corporation	2284		314.05	3768.6
Soba University Hospital	2950		405.625	4867.5
National Center of Isotopes & Radiotherapy	3157		434.1	5209.2
Ibrahim Malik Hospital	3577		491.84	5902.08
Ahmed Gasim Hospital	886		121.825	1461.9
Ibn Khaldoon Hospital	496		68.2	818.4
Total	19965	239580	2745.2	32942.4
All Hospitals in Khartoum State		597883	6850.7	82208.9

Table (4.21) Quantities of picric acid discharged from studied hospitals

Name o f Hospital	No. of creat. test/month	No. of creat. test/year	Q. of pic.a. mg/ month	Q. of pic.a. mg/ year
Khartoum Training Hospital	450		2052	24624
Khartoum North Training Hospital	9		41	492
Military Medical Corporation	62		283	340
Soba University Hospital	26		120	144
National Center of Isotopes & Radiotherapy	-		-	-
Ibrahim Malik Hospital	66		301	3612
Ahmed Gasim Hospital	30		136.8	1641.6
Ibn Khaldoon Hospital	-		-	-
Total	643	7716	2932	35184
All Hospitals in Khartoum State		9435	3585.33	43024

4.5 Results of x-ray Unit:

The amount of silver that can be recovered from discharged fixer solutions in studied hospitals in the last year is from 30.42 kg to 60.84 kg with concentration from 2400 to 4800 mg/L, 45.5% of it is discharged to the public sewer and 54.5% to seepage pits and others. Details of these amounts are summarized in table (4.22); table (4.23) gives details of total amount of silver recoverable from all hospitals in Khartoum state.

From the above two tables; percentage of silver recoverable from studied hospitals is approximately 89.33% of that from all hospitals in Khartoum State.

See plates (44), and (45)

Table (4.22) Quantities of silver recovable discharged from the studied hospitals

Name o f Hospital	No. of X-ray films used per month					Total Area m^2/month	Total Area m^2/year	Q. of SilverRec. kg/year	Silver Recovery	Final Disposal
	Type A	Type B	Type C	Type D	Total No.					
Khartoum Training Hospital	2893	330	2547	-	5770	356.11	4273.42	12.82 - 25.64	No	Hospital sewers
Khartoum NorthTraining Hospital	1230	690	308	46	2274	155.33	1863.96	5.6 - 11.2	No	Hospital sewers
Military Medical Corporation	1735	461	316	-	2512	208.62	2503.44	7.5 - 15	No	Hospital sewers
Soba University Hospital	145	127	91	-	363	19.55	234.6	0.704 - 1.408	No	Hospital sewers
National Center of Isotopes & Radiotherapy	170	155	65	-	390	22.7	272.4	0.82 - 1.64	No	Hospital sewers
Ibrahim Malik Hospital	490	360	116	52	1018	63.53	762.36	2.3 - 4.6	No	Hospital sewers
Ahmed Gasim Hospital	85	184	89	-	393	13.35	160.2	0.5 - 1.0	No	Hospital sewers
Ibn Khaldoon Hospital	45	34	21	-	90	5.91	70.92	0.21 - 0.42	No	Hospital sewers
National Health Laboratory	-	-	-	-	-	-	-	-	No	Hospital sewers
Total						845.1	10141.2	30.42 - 60.84	No	Hospital sewers

Table (4.23) Quantities of silver - recovable discharged from all hospitals in Khartoum State

Name of Hospital	Year	No. of X-ray films used per year					Total Area m^2/year	Q. of silver-recovable kg/year
		Type A	Type B	Type C	Type D	Total No.		
Federal Hospitals	2000	53247	63343	56997	2652	173577	7679.3	23.04 - 46.08
	2001	59797	71893	63002	3593	195633	8632.6	25.9 - 51.8
State Hospitals	2000	17994	17415	9018	2366	46793	2448.5	7.35 - 14.7
	2001	20068	18741	10382	2389	51532	2719.9	8.16 - 16.32
Total	2000						10127.8	30.4 - 60.8
	2001						11352.5	34.06 - 68.12

4.6 Results of experiments:

There are 26 samples were taken from various sources in the 4 biggest hospitals in addition to one sample from the National Health Laboratory, results of experiment are listed in table (4.24) and efficiency of treatment units is listed in table (4.25).

Table (2.25) Efficiency of the treatment units

Name of Hospital	Name of unit	Removal Ratio (%)		
		COD	BOD	S.S.
Khartoum North Training Hospital	Septic tank (Central lab.)	15.2	58.5	28.3
	Septic tank (x- ray unit)	21	32.6	19.75
Military Medical Corporation	Wetland	31	75	90
	Wetland	65	85	90
	Septic tank (Central lab.)	3.2	2	18.4
Soba University Hospital	Stabilization Ponds	83.7	75.7	92

Table (4. 24)   Results of experiments

No. of Sample	Date	Name Of Hospital	Source Of Sample	pH	COD mg/l	BOD mg/l	S.S. mg/l	Remark
1	21/6	Khartoum North Training H.	Central Lab.	7.3	1120	390	226	Septic tank, inlet
2	21/6	Khartoum North Training H.	Central Lab	6.9	950	250	162	Septic tank, outlet
3	28/6	Khartoum North Training H.	X-ray unit	7.2	1520	475	810	Septic tank, inlet
4	28/6	Khartoum North Training H.	X-ray unit	7.0	1200	320	650	Septic tank, outlet
5	3/7	Khartoum Training H.	Last manhol	6.9	1860	602	4660	Surcharged manhole with very high floating solids
6	10/7	Military Medical Corporation	Wetland	7.9	1380	480	1580	Influent (from tanker before running to wetland)
7	10/7	Military Medical Corporation	Wetland	8.1	1220	212	190	Under casuality culvert (two thirds of wetland)
8	10/7	Military Medical Corporation	Wetland	8.3	940	119	150	Effluent from the wetland
9	18/7	Military Medical Corporation	Casuality	8.7	980	330	13	Effluent pond (surface disposal)
10	18/7	Military Medical Corporation	Nile River	7.9	260	21	330	Under old White Nile bridge
11	18/7	Military Medical Corporation	Nile River	7.9	240	12	340	Under new White Nile bridge
12	25/7	Military Medical Corporation	Central Lab.	7.0	1260	350	490	Septic tank, inlet
13	25/7	Military Medical Corporation	Central Lab.	7.0	1220	343	400	Septic tank, outlet
14	25/7	Military Medical Corporation	Nile River	7.1	165	6	2390	Under old White Nile bridge
15	2/8	Military Medical Corporation	Nile River	7.3	180	6	480	Under new White Nile bridge

- continued

No. of Sample	Date	Name Of Hospital	Source Of Sample	pH	COD mg/l	BOD mg/l	S.S. mg/l	Remark
16	2/8	Military Medical Corporation	Nile River	7.3	165	6	680	Before new White Nile bridge
17	7/8	Military Medical Corporation	Wetland	7.5	1580	212	205	Influent (from tanker before running to he wetland)
18	7/8	Military Medical Corporation	Wetland	7.7	1420	68	30	Under casuality culvert (two thirds of the wetland)
19	7/8	Military Medical Corporation	Nile River	7.2	550	31	20	End of the wetland
20	13/8	Military Medical Corporation	Laundry	6.5	1620	381	24	First manhole
21	13/8	Military Medical Corporation	Refferd clinic	7.2	520	187	15	Effluent pond (surface disposal)
22	13/8	Military Medical Corporation	Families H.	7.3	960	312	10	Outlet from soakaway well to wetland
23	20/8	Soba University H.	Anaerobic P.	6.5	1536	437	270	Iffluent
24	20/8	Soba University H.	Facultative P.	6.7	380	418	90	Iffluent
25	20/8	Soba University H.	Maturation P.	7.2	300	119	40	Iffluent
26	20/8	Soba University H.	Maturation P.	7.2	250	106	21	End of the pond
27	26/8	National Health Laboratory	Last manhol	7.5	1920	615	3900	Surcharged manhole with very high floating solids

4.7 Discussion of the results:

4.7.1 Statistical data:

The study covers a wide range of hospital's types and sizes, so the result can be generalized easily to all hospitals in Sudan. Data summarized in table (4.1) show that number of hospital's bed is varying from 1057 (Military Medical Corporation) to 32 beds (Ibn Khaldoon Hospital). The occupancy ratio is varying from 90.45% (National Center of Isotopes and Radiotherapy) to 39.8% (Ibn Khaldoon Hospital), and the employees per bed is varying from 3.75 (Ibn Khaldoon Hospital) to 1.81 (Khartoum North Training Hospital). There are only 4 hospitals have sisters and doctors houses inside the hospital, their capacity is varying from 125 (Khartoum North Training Hospital) to 30 in Ahmed Gasim Hospital.

4.7.2 Water and wastewater flow rates:

Results in table (4.2) show that the estimated water consumption is varying from 395 l/bed.d (Khartoum Training Hospital) to 380 l/bed.d (Ibrahim Malik Hopital) except in Khartoum North Training Hospital (430 l/bed.d), which may due to the big capacity of sisters and doctors houses. Results in table (4.3) show that the estimated wastewater produced is varying from 355 l/bed.d (Khartoum Training Hospital) to 340 l/bed.d (Ibrahim Malik Hopital) except also in Khartoum North Training Hospital (387 l/bed.d), which may due to the same reason. From results in tables (4.2) and (4.3), ratio of bed occupancy does not affected on the water consumption and wastewater production.

4.7.3 Septic tanks and seepage pits:

Although the volumetric efficiency of seepage pits is more than 100%, the actual efficiency is less than that, because most of them are clogged due to the incorrect design of septic tanks.

4.7.4 Laboratories:

- Sodium Cyanide: is excepted to be very toxic to aquatic life and terrestrial, and exposure to as little as 50 to 150 mg can cause immediate collapse and death, and chronic exposure to low levels of cyanide is suspected to be responsible for various neurpathic and thyrotoxic conditions in human [39]. As shown in table (4.20), all hospitals in Khartoum State discharge 6850.7 mg/month (228.4 mg/day), and due to the dilution factor it can not be significant.
- Picric Acid: is a phenolic compound and there is no information found about the fatal dose, but repeat exposure may cause liver and kidney damage [39]. As shown in table (4.21), quantity of picric acid discharged from all hospitals in Khartoum State is 3885 mg/month which might be considered not big, but it need further studying because picric acid transfers rapidly in the ground layers [39].

4.7.5 X – Ray Units:

The regulatory level of discharging silver is 5 mg/L, and the concentration of silver discharged from hospitals is varying from 2400mg/L to 4800 mg/L, which is considered too much to the regulatory level.

4.7.6 Results of Experiment:

As shown in table (4.25), efficiency of wetland is good, particularly in removing BOD and S.S.

CHPTER FIVE

CONCLUSIONS AND RECOMMONDATIONS

5.1 Conclusions:

- Poor management practices of sanitation are prevailing out in the majority of hospitals in Khartoum State.
- The consequences are many health and environmentally risks.
- Every day nearly 2585 cubic meters of wastewater, considered to be hazardous, are discharged from hospitals to the subsurface water, Nile River, and the municipal net without pretreatment.
- Annually more than 68 kg of pure silver discharged from x-ray units to the hospital sewers without recovering.
- Lack of awareness regard the hazardous characteristics of this waste.

As a result of these practices water sources and soil may be polluted and thus, the community is exposed to infectious and toxic effects.

There are number of reasons found to be the causes of these improper management of sanitation practices, some of the common reasons are listed below:

1. Lack of regulatory framework;
2. Absence of a national policy for the hospital wastewater management;
3. Lack of awareness about the inherent hazards caused by improper management of hospital wastewater;
4. Improper design for the treatment units;

5. Insufficient evidence regards the negative impact of the improper management of hospital wastewater and insufficient information on sound management options and their benefits on certain decision makers; and
6. Insufficient allocation of financial and human resources.

5.2 Recommendations

It essential to understand that hospital wastewater management is an integral part of health care, and that creating harm through improper wastewater management reduces the over all benefits of health care. Hospital must be concerned and be fully responsible for safety managing of wastewater they produce.

Basic steps are needed for safe management, those are:

1. Assessing and evaluating wastewater management practices and their impact;
2. Selecting safe, environmentally sound, and sustainable wastewater management options; and
3. Raising awareness among the decision makers.

Based on results of this study, the following basic recommendations can be adopted to achieve the desired level of wastewater management in hospitals:

1. Ensure minimal safety requirements

Although there is no safe solution for the disposal of sewage from a hospital that can not afford compact sewage treatment plant, but for hospitals that apply minimal programmes, the following, which is recommended by the WHO [(4)], should be implemented to minimize health risks:

- Patient with enteric diseases should be isolated in wards where their excreta can be collected in buckets for chemical desinfection; this is utmost importance in case of cholera outbreaks.

- No chemicals or pharmaceuticals should be discharged into sewer.
- Sludges from hospitals should be dehydrated on natural drying beds and then incinerated together with solid infectious waste.
- Sewage from hospitals should never be used for agricultural or aquacultural purposes.
- Hospital sewage should not be discharged into natural water bodies that are used to irrigate fruits or vegetable crops, to produce drinking water, or for recreational purposes.

Small – scale rural hospitals that apply minimal waste management programmes may discharge their wastewater to the environment. An acceptable solution would be natural filtration of the sewage through porous soils, but this must take place outside the catchment area of aquifers used to produce drinking- water or to supply water to the hospital [(4)].

2. Insure safety for wastewater treatment system personnel

This section provides information regarding health precautions and other preventive measures recommended [(39)] for personnel who work with hospitals wastewater treatment systems.

1. Those personnel who are in contact with wastewater, or who work in or inspect wastewater treatment plants, must keep their basic immunizations current. Immunizations required include polio, tetanus, and diphtheria.
2. Wastewater treatment plant personnel must not eat, drink or smoke when performing maintenance on or inspecting equipment which may be a direct source of contamination.
3. In the event of a significant wastewater spill, those cleaning the area must wear coveralls, rubber boots, rubber gloves, hair coverings, and face shields.

Upon completion of spill clean –up, contaminated clothing must be removed and placed in a plastic bag for laundering. Clean-up personnel must take a hot shower, using plenty of soap and water, promptly after spill clean-up is completed. Caution must be exercised when cleaning sewage spills on confined spaces. The gases given off by sewage can be explosive, toxic and/ or displace the oxygen in the space.

4. Clean-up of wastewater spills may be accomplished using detergent and water, followed by thorough rinsing.
5. Disinfection of the spill area is required in food service, berthing, and medical spaces. Disinfection may also be helpful in preventing odors in other areas.
6. In the event of a major leak or spill, the cognizant medical department must be notified.

3. Develop a national policies for proper treatment and disposal of hospital wastewater

Plan for treatment and disposal of hospital wastewater should be developed. This can be done through the following steps:

1. Establish a policy commitment and responsibility for hospital wastewater management;
2. Conduct a national survey of hospital wastewater management practices;
3. Develop a national guidelines;
4. Develop regulations and standards for hospital wastewater management;

4. Reduce hazardous pollutants discharged with the hospital wastewater

There are a number of steps establishing a successful hospital pollution prevention program. These steps include:

1. Reviewing and describing in detail the processes within the hospital to determine the sources of pollutant to define a baseline inventory to be used to set goals and evaluate progress
2. Identifying potential pollution prevention opportunities for the facilities.
3. Selecting the best pollution prevention options for the hospital and implementation these choices.
4. Evaluating the pollution prevention program on a hospital-wide basis as well as evaluating specific pollution prevention projects.
5. Maintaining and sustaining the pollution prevention program for continued growth and continued benefits to the hospital. Re-evaluating the program as economic situations change and/or process equipment requires upgrading.
6. Utilizing the checklist [40] in annex (5.1) as a means of establishing and monitoring the hospital waste reduction program. Not all categories will apply to each medical facility and the situation may be unique.

5. Treat and dispose wastewater by safe and environmentally sound methods

Suitable and efficient technologies and practices should be used in hospitals; some of them are listed below:

1. Corrected design septic tank: Because improper design of septic tank is the common problem, the researcher prepared a computer program to calculate the correct dimensions of the hospital septic tank with its drawings (see annex (5.2));
2. Increase sludge storage capacity of septic tank by 20%: It is known that synthetic detergent are likely to cause foaming in septic tank and slow up the digestion, Hill [41]recommended that sludge storage capacity of septic tank should be increased by 20%;

3. Using interceptor for laboratories wastewater;
4. Using grease trap for kitchen wastewater;
5. Adding filter after septic tanks;
6. Using other methods than seepage pits: Seepage pits are primarily made to facilitate the disposal of the septic tanks effluent, but should never be used where there is neither a likehood of contaminating ground-water nor where adequate subsurface tile disposal fields or other alternative method can be provided [(42)]. Pit excavation should not extend into the ground-water table;
7. For those hospitals near sewerage net works it better to connect to it; and
8. Strict monitoring should be implemented on all existing boreholes used for drinking water or food industry.

ANNEX

ANNEX (1)

Heavy metals and organic compounds with maximum concentration regulatory levels [43]

Pollutants	**Regulatory level (mg/L)**
Arsenic	5.0
Cadmium	1.0
Lead	5.0
Selenium	1.0
Barium	100.0
Chromium	5.0
Mercury	0.2
Silver	5.0
Tetrachloroethylene	0.7
Vinyl chloride	0.2

Annex (2)

Annex (2.1)

Pit Latrines Provisional Criteria

Description	Criteria
Life of pit	5-15 years
Filling rate(above water table)	0.06 m^3/c/year
Filling rate(below water table)	0.04 m^3/c/year
Maximum width	2 m
Preferred minimum free space above contents	1 m
Period after use before re-digging	1-2 years
Size of vent pipe	200 mm
Color of vent pipe	Black
Position of vent pipe	South or sunny side
Lining requirement	Varies
Slab level	200 mm minimum above ground

Source: Khartoum Sanitation Report

Annex (2.2)

Septic Tank Provisional Criteria (see annex (3.3))

Total liquid volume = 3 x waste flow (m^3/head) x No. of persons using the tank

First compartment = 2 x waste flow x No. of persons

Second compartment = 1 x waste flow x No. of persons

Interval between desludging = waste flow (m^3 /hd d) / 0.04 (m^3 /hd yr)

Soakaways in Khartoum and Omdurman

The following is known about septic tank soakaway design in Khartoum and Omdurman:

Typical depths	:	8 m to 30 m
Typical depth below water table	:	1 m to 2 m
Internal diameter	:	1.5 m to 2 m
External filter	:	None
Lining	:	Fully fired brick or partly fired brick with cement plaster. Joints are mortared but openings may be left in the lowest 2 m.

Source: Khartoum Sanitation Report

Annex (3.3)

SURVEY QUESTIONNAIRE (1)
HOSPITALS WASTEWATER MANAGEMENT

Name of Hospital: ....

Location of Hospital: ....

Hospital category (tick):

- ❑ Federal ( )
- ❑ Stat ( )
  - ❑ District ( )
  - ❑ Sub-district ( )
- ❑ Private ( )

Hospital type (tick):

- ❑ Specialist ( )
- ❑ General ( )

No. of employee: ....

No. of inpatient: .... /day

No. of outpatient .... /day

Total No. of bed: ....

Bed occupancy: ....

Water supply:

- ❑ Ground water ( )
- ❑ Municipal net ( )
- ❑ Ground water & Municipal net ( )

Total water consumption .... m^3/d

Comment: ....

Wastewater produced .... m^3/d

Comment: ....

Type of wastewater treatment:

- ❑ On-site treatment ( )
  - ❑ Grease trap ( )
  - ❑ Septic tank ( )
  - ❑ Filter ( )
  - ❑ Others ....

- ❑ Off-site treatment ( )
  - ❑ Public sewers ( )
  - ❑ Pretreatment and then connection to public sewers( )

Final disposal of wastewater:

- ❑ Land-based ( )
  - ❑ Soakaway pit ( )
  - ❑ Seepage pit ( )
  - ❑ Soakaway well ( )
  - ❑ Surface disposal ( )
- ❑ To water environment ( )
- ❑ Evaporation ( )
- ❑ Other ....

Wastewater reuse:

- ❑ Yes ( )
- ❑ No ( )

If yes, nature of reuse ....

Comment: ....

....

SURVEY QUESTIONAIRE (2)
ON-SITE TREATMENT SYSTEM

Hospital Name: ....

Grease Trap:

G.T No.	Total Depth (h)m	Liquid Depth (h_1) m	Width (b) m	Length (L) m	No. of Compartment	Inlet Tee	Outlet Tee	Detail Type	Performance	Remark

Septic Tank:

S.T. No.	Total Depth (h) m	Liquid Depth (h_l) m	Width (b) m	Length (L) m	No. of Compartment	Inlet Tee	Outlet Tee	Detail Type	Performance	Remark

Sludge removal/treatment:

Removal: ....

Final disposal: ....

Sludge reuse:

- Yes ( )
- No ( )

If yes, type of reuse ....

Filter:

Filter No.	Total Depth m	Filtration Depth m	Area of filtration	Size of Gravels mm	Depth of Gravels m	Size of filtered water compartment	Remark

Seepage pit :

S.P.No.	Diameter m	Total Depth m	Water Depth m	Performance	Remark

Other: ....

....

SURVEY QUESTIONAIRE (3)
COLLECTION SYSTEM

Pipes:

- Down pipes:

Location*	Type	Size	Fittings type	Condition	Remark

- Horizontal pipes:

Location	Type	Size	Slope	Condition	Remark

Internal fitting (floor drain):

Location	Type	Size	Condition	Remark

Water closet:

Location	Type	F.F.L W.R.T.F[a]	Trap Type	Condition	Remark

Hand basin:

Location	Type	Hot water	Cold water	Trap Type	Drain To	Condition	Remark

Manhols:

Location	B.M[b] (B.W[c].or R.C[d].)	Size m*m	Depth (m)	Cover Type (H.D[e]or N.H[f].)	Sign of sircharge	Cracks	Remark

Galley Trap:

Location	Type	B.M.	Condition	Remark

Bathroom:

Location	Type	F.F.L.W. R.T.F.L	Connected To (floor drain or vertical down pipe)	Condition	Remark

* Location Key: A, B, C

A: Block Number or Name
B: Storey Number
C: Direction

a. Finished floor level with respect to tee level
b. Building material.
c. Brick work
d. Reinforced concrete
e. Heavy duty
f. Normal duty

SURVEY QUESTIONNAIR (4)

LABORATORIES WASTEWATER

Name of Hospital:..

Type of Lab. (tick):

- Haematology Lab. ( )
- Microbiology Lab. ( )
- Chemical Pathology Lab. ( )
- Histopathology Lab. ( )
- Immunology Lab. ( )
- General (casuality) Lab. ( )
- Others Lab. ....

Comment: ....

....

....

Lab.	Type of test	Type of organ	No. of test/month

No. of x-ray's films:

A	....	/ month
B	....	/ month
C	....	/ month
D	....	/ month
Total average	....	/ month

Silver recovery:

- ❑ Yes ( )
- ❑ No ( )

The final disposal of chemicals waste:

- ❑ Hospital sewers ( )
  - ❑ With pretreatment ( )
  - ❑ Without pretreatment ( )
- ❑ Out of hospital sewers ( )

Annex (5)

Annex (5.1)

Hospital Pollution Prevention and Reduction Checklist

MATERIALS MANAGEMENT		
Category	**Type of Problem**	**Waste Reduction Activities**
Hazardous Materials	Hazardous wastes, Cleaning products, and all other chemicals.	All hazardous materials and wastes should be labeled and stored according to federal, state and local regulatory requirements.
		Segregate non-compatible materials and provide secondary containment.
		Floor drains should be eliminated in all areas where hazardous materials are handled or stored.
		Material Safety Data Sheets (MSDSs) should be readily available for all of the materials used, and accessible to all staff.
		Label containers, instruments, and processes that hold or use problem materials so that each user is aware of his or her responsibility for proper use and disposal.
		Keep bottled chemicals in secured storage, on low shelves (never over sinks) or in storage cabinet with latching doors.
		Prevent bottle breakage and spills by using trays with lips or other specialized carrying containers to transfer chemical bottles between storage areas and labs.

LABORATORIES		
Category	**Type of Problem**	**Waste Reduction Activities**
Chemistry Labs	Mercury, copper, Chromium, cyanide	Lab managers and analysts should be aware of the available options and chose the one that produces the best results with the least amount of waste.
Hematology	Cyanide, Formaldehyde, Chloroform and other solvents, xylenes, Mercury, copper, Chromium, zinc	Use cell sorter/counting instruments with cyanide-containing cell lysing solutions.
		The manual iron-cyanide test yields a concentrated cyanide solution that should be collected, stored in secondary containment, and disposed of as hazardous waste.
Chemistry and Hematology labs		Waste from atomic absorption (AA) standards for heave metals should be collected and disposed of as hazardous waste. Procedure standards only as needed.
		Minimize use of xylenes for extractions and be sure to collect any waste. Terpene-based solvents (Hemo-D) may be substituted for xylenes used for slide cleaning in some applications.
		Collect and dispose of properly.
		Solvent recovery through distillation is economically feasible in some situations.
		Waste solvents should be collected for disposal as hazardous waste. Included are chloroform and methylene chloride, solvents used for TLC analysis. Minimize extraction sample sizes to reduce the quantity of solvents used.
	At least one albumin method used a highly concentrated chromium reagent.	Collected for disposal as a hazardous waste.

LABORATORIES (CONTINUED)		
Category	**Type of Problem**	**Waste Reduction Activities**
	At least one total protein method uses a concentrated copper reagent.	Collected for disposal as a hazardous waste.
	At least one preservative for stool samples contains a concentrated copper solution.	Collected for disposal as hazardous waste. At least one
		Substitute for glucose tests containing zinc.
Pathology/ Histology	Mercury, glutaraldehyde, formaldehyde, alcohols, xylene, other solvents	Waste glutaraldehyde, formaldehyde, alcohols, xylenes, and other solvents should be collected and disposed of as hazardous waste.
		Store activated glutaraldehyde, formaldehyde, alcohols, xylene and other solvents for 14 to 21 days. After that time discharge.
	Zanker’s solution and B5; especially problematic because they contain high levels of mercury.	Discourage the use whenever possible. Expending the additional time and care necessary to obtain excellent specimens using other (non-metallic) fixatives.
Microbiology	Reagents containing heavy metals (such as copper and silver) and solvents	All staining supplies should be stored in secondary containment.
		Both waste and contaminated rinsate volumes can be reduced if slides are stained with a few drops of solution rather than dipping bath.
		If stains contain hazardous or metal ingredients, rinse slides and containers to a hazardous waste container.

LABORATORIES (CONTINUED)		
Category	**Type of Problem**	**Waste Reduction Activities**
Immuno-diagnosis	Copper sulfate solutions and mercury	Copper sulfate solutions should not be discarded or rinsed into the sewer.
		Find the alternatives to thimerisol used as a preservative in some buffer solutions; sodium azide is one example.
	Formaldehyde solutions, glutaraldehyde, alcohols, rinses from silver staining, Zanker's solution and Zinc sulfate.	All formaldehyde solutions and specimens stored in free solutions should be stored properly in secondary containment, on secured shelving, and away from sinks.
		Water solutions containing metals, including rinses from silver staining and Zanker's fixing should be collected and managed as a hazardous waste.
		Formaldehyde, glutaraldehyde, and alcohols should be stored properly and collected for proper disposal.
	Mercury	**Replace mercury-containing equipment with equipment that does not contain mercury.**
		Use some of the many available alternatives to mercury thermometers, including alcohol (red) and digital thermometers for equipment such as lab ovens and water baths.
		Make sure mercury spill cleanup kits are available in all areas where mercury-containing equipment in used.
		Make sure the individual designated by the hospital's environmental health and safety department cleans up all mercury spills. If your facility does not have such a person, instruct all employees in the proper handling and disposal (usually recycling) of mercury.

HEMODIALYSIS		
Category	**Type of Problem**	**Waste Reduction Activities**
	Disinfection of dialysis equipment and the associated reverse osmosis (RO) systems used to purify dialysis water can cause water pollution problems if formaldehyde-based disinfectants are used.	A solution of peracetic acid, acetic acid and hydrogen peroxide (such as Renalin or Actril) can be substituted for formaldehyde-based disinfectants.
		RO units can be made compatible with peracetic acid disinfectants through pretreatment to remove any iron, which may react with the oxidizing solution and form holes in the membrane.
		Use of peracetic acid disinfectants with the small membrane cartridges and in the dialysis equipment itself can also reduce the volume of hazardous waste generated.
		Equipment that can be heat-disinfected may be available in the near future.
		Any dialysis unit that is still using formaldehyde for disinfection should collect all waste solutions and dispose of them as hazardous waste.

CENTRAL STERILIZATION		
Category	**Type of Problem**	**Waste Reduction Activities**
	Of the wide range of sterilizing processes used, there are certain cold sterilants (glutaraldehyde, formaldehyde, and phenols), and institutional dishwashers using caustic cleaners and ethylene oxide chambers.	Cold sterilizing solutions containing glutaraldehyde or formaldehyde should be minimized or eliminated where possible.
		Sonic sterilization may be used alone or in conjunction with solutions.
		Try using alternative liquid sterilants including, among others, formulations of peracetic acid, acetic acid and hydrogen peroxide.
		Steam sterilization (autoclaving) produces little or no chemical waste.
		Large industrial-type dishwashers may be used for sterilizations as well as cleaning.
		Use of ethylene oxide (EtO) requires air emissions control devices.
		Evaluate alternative methods including gas phase hydrogen peroxide, electron beam, gas plasma, and microwave.

NURSING,PATIENT CARE AND PHYSICIANS		
Category	**Type of Problem**	**Waste Reduction Activities**
	Disinfection supplies, medicines and other pharmaceutical products, and spills from mercury-containing equipment such as thermometers and blood pressure cuffs, selenium and zink	Use some of the available alternatives to mercury thermometers, such as electronic sensors, digital thermometers, and temperature strips.
		Clean up all mercury spills properly and completely.
		Whenever possible, prescribe non-metallic shampoos and medications.
		Evaluate drug ingredients for metals, and prescribe non-metallic alternatives when feasible.

HOUSEKEEPING		
Category	**Type of Problem**	**Waste Reduction Activities**
Phenolic disinfectants	Phenolic compounds are toxic and may bioaccumulate in the environment.	Eliminate use of phenolic disinfectant wherever possible. Consider substituting quatemary amine desinfictant.
		If phenols are used, keep concentrations to the minimum recommended by the manufacturer. Use - feed or auto feed systems that supply the appropriate dose when preparing a solution; prepare only the amount to be used.
		Store both types of concentrated disinfectants in secondary containment to avoid spill.
		Never discharge concentrated disinfectant solutions to the sanitary sewer.

PHARMACY		
Category	**Type of Problem**	**Waste Reduction Activities**
	Silver, selenium and other metals	Pharmacists recommend over-the-counter medications, suggesting less-toxic substitutes for hazardous formulations, including dandruff shampoos and zinc ointments.
Silver Solutions & Ointments		Silver nitrate solutions with silver concentrations above 5 ppm must be collected and disposed of as hazardous waste.
Chemical Storage and Disposal		Pharmacy personnel should inventory chemical stores periodically and properly dispose of all chemicals that are no longer used, including expired medicines.
		No pollutant-containing products should be dis-carded to the sanitary sewer. Substances to be aware of include hazardous wastes and all products containing silver, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium and zinc.
		Keep bottled chemicals in secured storage, on low shelves (never over sinks) or in storage cabinets with latching doors.
		Store acids separately from bases, and flammables separately from oxidizers
		Make sure all chemical containers are clearly labeled
		Provide secondary containment for all hazardous materials and waste storage.
Compounding		Prevent bottle breakage and spills by using trays with lips or other specialized carrying containers when transferring chemical bottles between storage and labs.
		Provide only minimum amounts and collect all waste.
		Pour or mix liquid chemicals within a tray or other secondary containment, so that spills will not reach a drain.
		When compounding powders, clean up "dust" using dry cleanup methods as soon as possible, so that chemicals will not reach the sewer during routing wet cleaning operations.

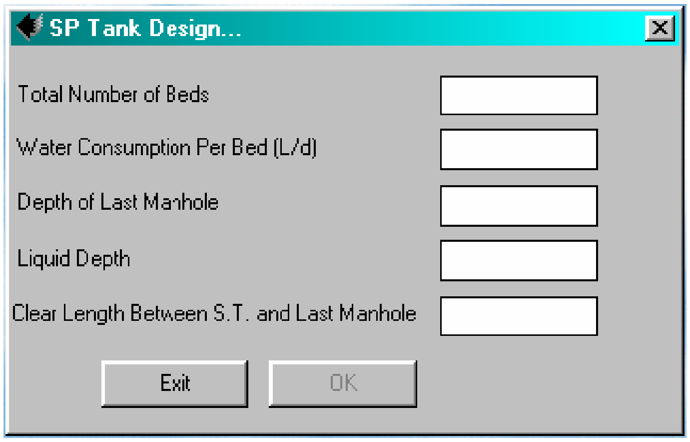
RADIATION THERAPY		
Category	**Type of Problem**	**Waste Reduction Activities**
Lead Shielding	Lead shielding to protect patients during radioactive therapy is normally either machined from lead blocks or poured in molds	All machining waste (from sawing, filing and washing operations) must be collected and disposed of as hazardous waste.
		Any wasted from washing, filing or other working of the casts should be collected and disposed of as hazardous waste.
Radioactive Waste	Radioactive waste results from the use of tracers and other radioactive diagnostic and treatment procedures.	Follow all Nuclear Regulatory Commission (NCR) regulations concerning the disposal and storage of radioactive materials and waste.

RADIOLOGY		
Category	**Type of Problem**	**Waste Reduction Activities**
	Silver can be recovered effectively and economically with silver recovery units. Silver (in spent processor solutions), chromium (in developer cleaners) and selenium (in some toners)	Haul off-site for recycling.
		In large facility, centralized treatment of spent fixer reduces the amount of sampling required as well as the number of systems to be maintained.
		If processors are cleaned with a chromic acid solution such as Kodak's Liquid Developer System cleaner, spent cleaning solutions and rinse water must also be disposed of as a hazardous waste.
		Spent photochemicals containing selenium such as Kodak Rapid Selenium Toner must be disposed of as hazardous wastes.
		Newer, well-maintained equipment generally uses less water and smaller volumes of chemicals, with reduced carry-over of silver-bearing fixer into the rinse water.
		Films should be recycled for silver content.

FACILITIES		
Category	**Type of Problem**	**Waste Reduction Activities**
Plumbing	Mercury from inappropriate spill cleanup practices and broken equipment often finds its way to sewer lines and umps, where it settles at low points such as umps and traps.	Whenever sewer lines, traps, or sumps are moved or cleaned, caution should be taken to avoid spilling the contents in case mercury is present. Non-water contents must be handled as hazardous waste unless proven otherwise.
Laundry		Make sure no hazardous materials enter the laundry (e.g. thermometers, rags used to clean up hazardous materials spills).
		Reduce water use by recycling gray water and using water-efficient equipment such as tunnel washers and other automated systems.
		If wastewater discharges from laundry facilities contains significant amounts of metals as well as organics, several "pretreatment" options (used by laundries in other settings) are available, including: * Equalization * Coagulation/flocculation * Dissolved air flotation * Micro/ultra filtration * Clarification * Oil/water separation Store laundry chemicals properly in secondary containment, with incompatible substances separated from each other.

FACILITIES		
Category	**Type of Problem**	**Waste Reduction Activities**
Water Purification Systems	Treatment systems using ion exchange resins and/or reverse osmosis (RO).	Chemicals used for cleaning and disinfection of deionized Water and reverse osmosis systems should be stored properly in secondary containment, with acids and bases separated, on secured shelving and away from sinks.
	Laboratory reagents and to prepare dialysis solutions.	Disinfection of reverse osmosis and deionized water should be accomplished without the use of formaldehyde. Sodium hypochlorite, bromine and peracetic acid disinfectants are appropriate substitutes.
Cleaning and Maintenance Products	May contain Pollutants such as metals, solvents, and tri - butyl tin	If Possible, eliminate use of the following problem products. *Floor waxes or wax strippers that contain zinc. *Toilet cleaning and disinfection products containing tri - butyl tin. *Carpet and upholstery cleaners that contain tri – butyl
		Do not use cooling water system additives that contain copper , chromium, or tri - butyl tin.
		Paint and Paint strippers contain solvents and metals that should not be disposed of into the sewer or storm drain system. Solvents and thinners used with oil - based paints should be filtered and reused.
		Limit or eliminate use of copper -based root control products.
		Maintain pools, spas, and fountains without use of copper - based Algaecides.

Annex (5.2)



program Codes:

Code 1:
frmSpTank1:

```
Private Sub cmdExit_Click()
    Unload Me
End Sub

Private Sub cmdPrint_Click()
    cmdPrint.Visible = False
    cmdExit.Visible = False
    Me.PrintForm
    cmdPrint.Visible = True
    cmdExit.Visible = True
End Sub
```

Code 2:
frmSPTank2:

```
Private Sub cmdExit_Click()
    Unload Me
End Sub

Private Sub cmdPrint_Click()
    cmdPrint.Visible = False
    cmdExit.Visible = False
    Me.PrintForm
    cmdPrint.Visible = True
    cmdExit.Visible = True
```

Code 3:
frmStarter:

```
Dim Qd As Single, V As Single, A As Single
Dim L As Single, W As Single, ht As Single

Private Sub cmdExit_Click()
   End
End Sub

Private Sub cmdOK_Click()
   Dim frm As Form
   ht = Val(hl) + Val(hm) + 0.04 * lm
   Qd = Nb * Qb / 1000
   V = 3 * Qd
   A = V / ht
   W = Sqr(2 * A)
   L = 2 * W
   If Qd > 3.5 Then Set frm = frmSpTank1 Else Set frm = frmSPTank2
   frm.Label1.Caption = "  L= " & Int(100 * L) / 100 & "  m"
   frm.Label2.Caption = "  W= " & Int(100 * W) / 100 & "  m"
   frm.Label3.Caption = "  ht= " & Int(100 * ht) / 100 & "  m"
   frm.Label4.Caption = " For Qd = " & Int(100 * Qd) / 100 & " m3 "
   frm.Show
End Sub

Private Sub hl_Change()
   IsNum hl
   EnableOk
End Sub

Private Sub hm_Change()
   IsNum hm
   EnableOk
End Sub

Private Sub lm_Change()
   IsNum lm
   EnableOk
End Sub

Private Sub Nb_Change()
   IsNum Nb
   EnableOk
End Sub

Sub IsNum(x As TextBox)
   If IsNumeric(x) Then x.ForeColor = vbBlack Else x.ForeColor = vbRed
End Sub
```

```
Sub EnableOk()
   Dim o As Object, ok As Boolean
   ok = True
   For Each o In Me.Controls
      If TypeOf o Is TextBox Then ok = ok And IsNumeric(o)
   Next o
   cmdOK.Enabled = ok
End Sub

Private Sub Qb_Change()
   IsNum Qb
   EnableOk
```

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